Chemical Engineering Progress

PILOT PLANT
for separating
spent nuclear fuel

DECEMBER 1955

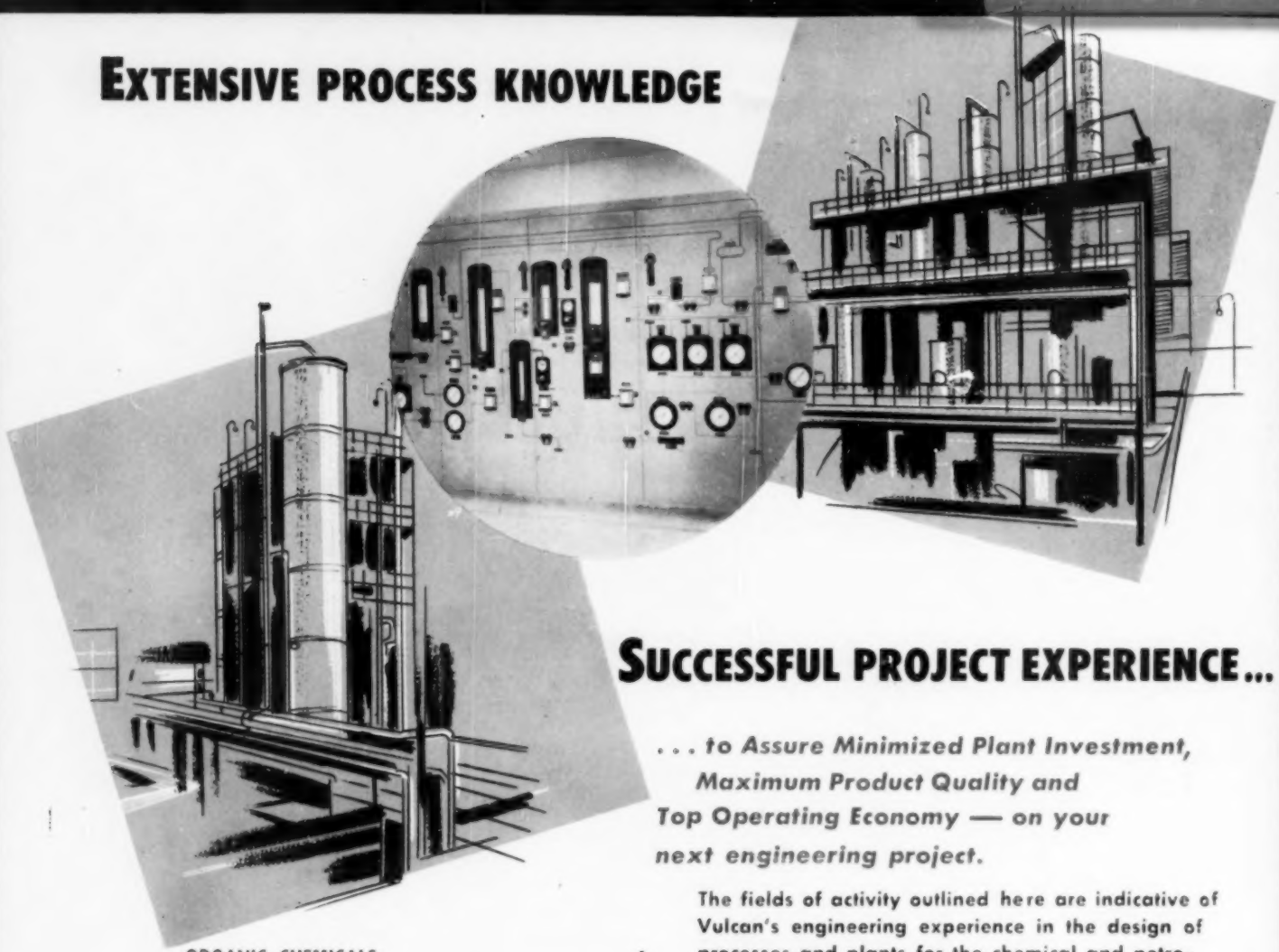
economic balance calculations

guide to ENGINEERING INVESTMENT

WITH

- **FERMENTATION—a chemical engineering process**
- **ION EXCHANGE—in the fine chemical industry**
- **WASTE DISPOSAL USES DEEP WELLS**
- **INDUSTRY SPONSORED SCHOOLS FOR PROFS**
- **CENTRIFUGALS—BUBBLES—PHOTOCHEMICAL EQUIPMENT**

EXTENSIVE PROCESS KNOWLEDGE



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Chemical Engineering Progress

DECEMBER, 1955 • Volume 51, No. 12

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Trends—This is the time of year when budgets are being set up. C.E.P. reports on an informal survey of executives' opinions.

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The venture worth method for economic balances / 533

John Happel—Too often, intuition is an important factor in estimating conditions which will produce a maximum financial return from chemical engineering investments. To improve upon this situation, author Happel offers a concise method which should be of wide interest to chemical engineering management.

Fermentation—a chemical engineering approach / 540

E. L. Gaden Jr.—It's time to regard microbiological processes as enzyme-catalyzed chemical reactions which should respond in a predictable manner to changes in process variables.

Economic considerations in process design / 544

R. B. Smith & Thorpe Dresser—Designing process equipment to improve efficiency involves addition of small increments of equipment and noting the effect on economics of performance. The authors show how to avoid the obscuring of unprofitability of the last incremental portion added through undue attention to the large profits expected from the total unit.

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Cover design by Milton Wynne Associates

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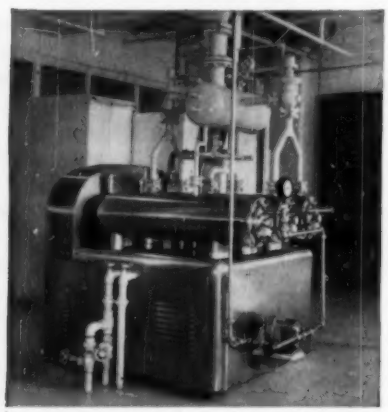

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CEP what's in this issue...

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Ion exchange in the fine chemicals industry / 547
James Gillin—Ion exchange is shown to be used in a number of interesting ways which may be suggestive of applications in other fields. Among the methods discussed are neutralization without salt formation, ion interchange, adsorption of complex molecules present in trace quantities in broth, etc.

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W. R. Page, C. J. Raseman, E. I. Goodman, & C. H. Scarlett—Description of and operating results from a pilot plant at Brookhaven for separating radioactive compounds from spent reactor fuel by distillation, preceded by fluorination.

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W. T. Anderson, Jr.—Factors are described which are considered in planning for the use of high intensity mercury vapor arc radiation sources, automatically controlled, for the promotion of chemical reactions—particularly chlorination.

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By several classifications, to make easy the finding of articles, both technical and news, in past issues. Contains official listing of officers of A.I.Ch.E. for 1956, with election results.

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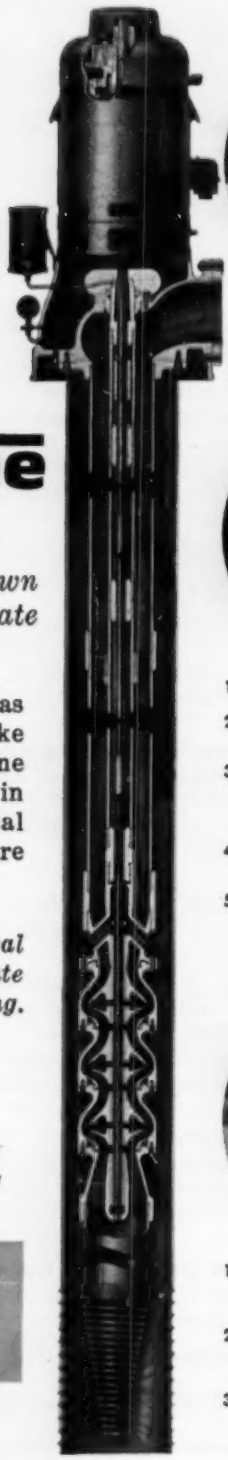

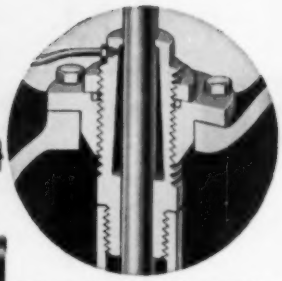

This easily accessible assembly provides means of putting tension on oil tubing, making a rigid, taut, non-vibrating bearing and shaft enclosure.

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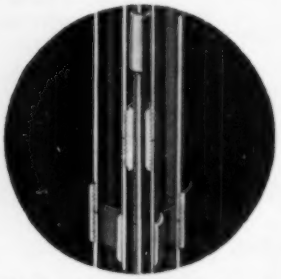

1. Butt-joint column pipe is usually furnished in 10 ft. lengths.
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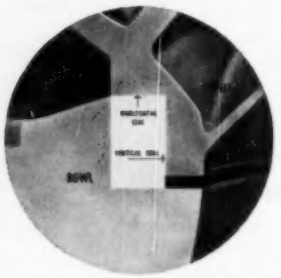

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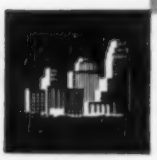

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LETTERS TO THE EDITOR

What's Your Opinion?

I have been following Chemical Engineering Progress . . . feel it has improved considerably, both in format and content. It still has a distance to go . . . In addition, the new *Journal* should attract an increasing number of high quality papers, and I would like to see the publications of A.I.Ch.E. play a dominant role in publishing important developments in chemical engineering. . . .

I am disturbed that C.E.P. has not developed a Letters to the Editor column of significance. . . . [Such columns] appearing prominently in publications of other societies [deal with] issues . . . freely and frankly in a manner which encourages the membership as a whole to feel . . . constructive progress toward the solutions of problems. . . .

Perhaps this reluctance to write may stem from the feeling [on the part of] many in the past that the Institute is not too democratic in its actual methods of operation. Recent changes in the membership rules giving voting privileges to Junior (now Associate) Members are most important [in that they] broaden the democratic base.

. . . [There is also] the feeling, which I have run into in the Southwest and the far West, that the center of gravity of the Institute swings around the Washington-New York center and that the people who are far west have little voice in the Institute.

I . . . would like to see A.I.Ch.E. grow and develop and play a more important role in the lives of chemical engineers . . . As an individual I have had little contact with the main Institute and [feel] that the possibilities of working in any constructive sense have been rather small. This is probably not true in such main centers as Los Angeles, Houston, or other larger cities where the Institute has sections . . . per-

(*Continued on page* 12)

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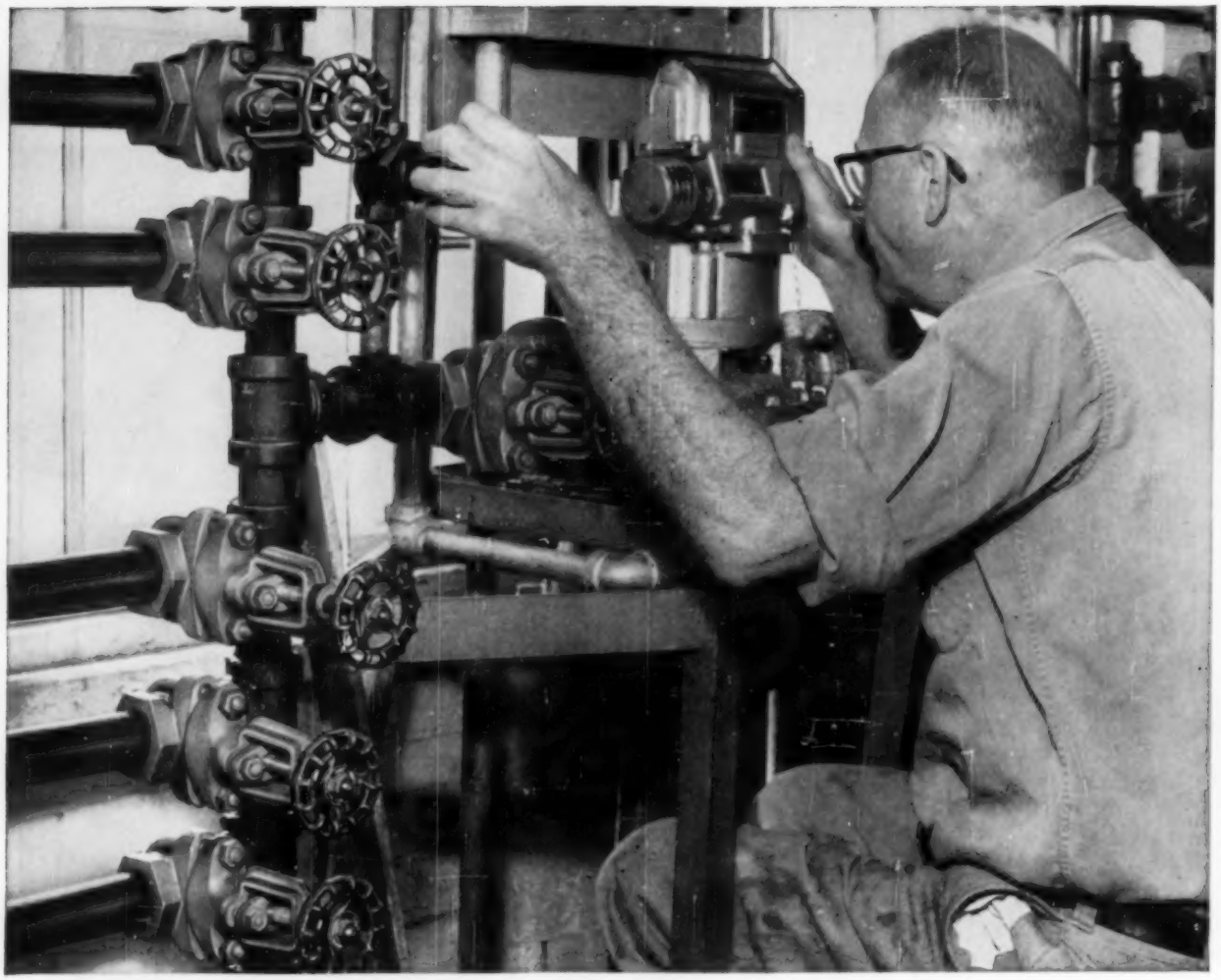

These Crane valves stay tight on soap oils and fatty acids

THE CASE HISTORY—Leakage through valve seats in raw materials supply lines posed a serious problem for Davies-Young Soap Co., Dayton—makers of various type soaps and cleaning fluids. Unwanted materials leaking past metering stations would infiltrate processing vats.

Four different makes of valves were tried before these Crane valves were installed. With all four, results were the same—seat leakage developed quickly; the valves lasted no more than 4 to 8 weeks.

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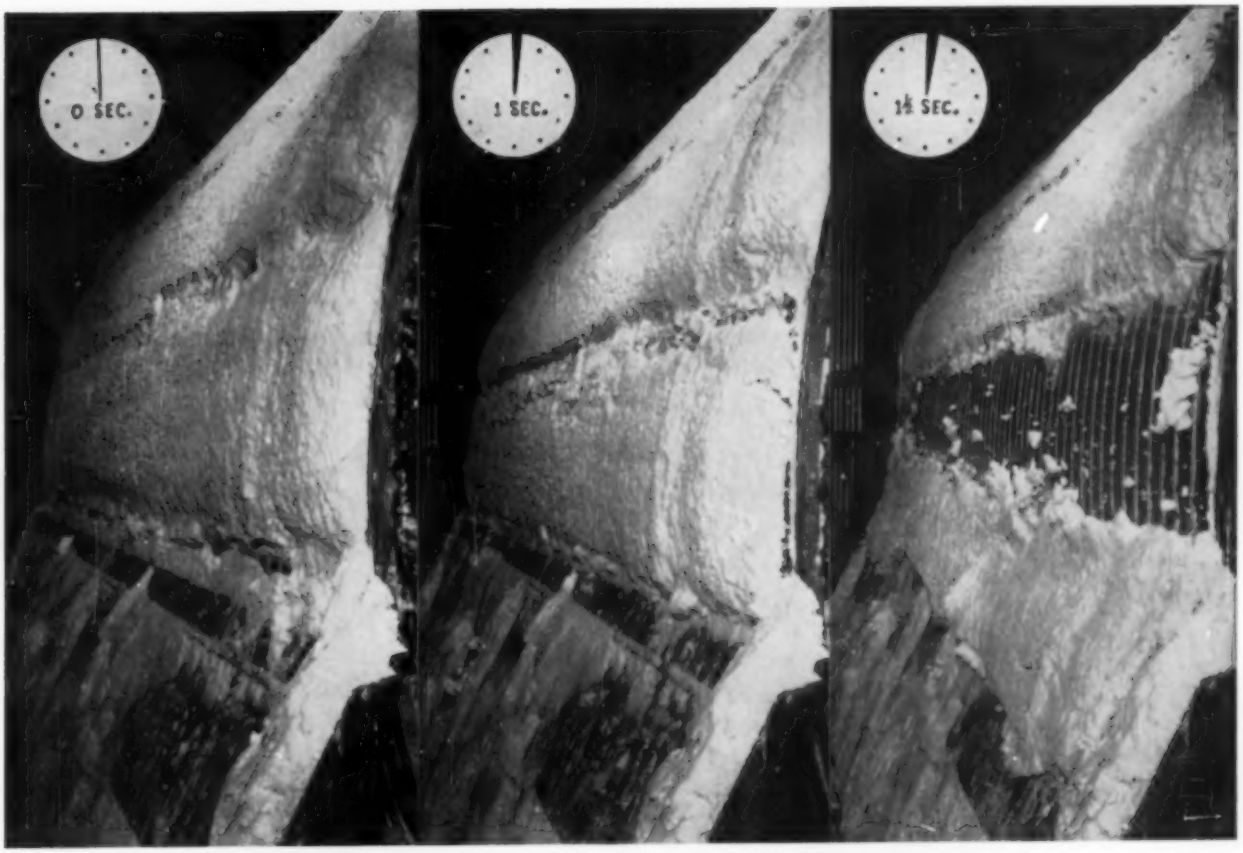

The high speed camera pictures show the Eimco Drum Filter with cake formed on the drum, cracked and leaving the panel clean.

SAVE WITH A SNAP!

Greater savings are being realized by many companies in filter media and filter down time where the use of a snap blow is practical for the product being filtered.

Snap blow on Eimco filters is accomplished by introducing high pressure air for a fraction of a second at the discharge point. This action on a heavy salt cake is shown above taken with high speed photography. The three successive pictures were taken only seconds apart as shown by the clock.

Advantages are in being able to move the scraper blade back so that it never touches the media and acts only as a deflector. The high pressure air helps keep the media free of blinding particles so that tonnage goes up — maintenance goes down.

Snap blow may be ordered with your Eimco filter, properly installed and regulated at the factory or, you may purchase a "snap blow" kit to install on your present fitler.

An Eimco engineer will be glad to advise the practicability of snap blow on your product. Write for more information.

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B-181

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- **Bulletin 455:**
  "Controlled Volume Pumps in Paper Making."
  Describes and illustrates more than 30 applications in leading mills—stock preparation, bleaching, water treating, conversion.
- **Bulletin 1253:**
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LETTERS TO THE EDITOR

(*Continued from page 6*)

haps I have been unfortunate in always living in cities or small towns in which A.I.Ch.E. was essentially inactive. A further complication lies in the competition for time of the other professional societies and their meetings. . . .It would be helpful [to have] comments of other members of the Institute as to what can be done to encourage a greater participation of those members living in [remote] areas.

JAMES H. WIEGAND

San Antonio, Texas

Reader Wiegand raises many issues of opinion not in our province to debate. On the issue of geographical representation may we present a few facts: 1955 Council membership—three from California; two from New York, Michigan; two from Ohio, Pennsylvania; one from West Virginia, Connecticut, Delaware, Oklahoma, New Jersey, Texas; elected this year were representatives from New York, Pittsburgh, Houston, Wisconsin, Massachusetts, and Indiana. We have made repeated editorial pleas for letters to the editor, the most recent being published in August, 1955, page 341. Editor

A Reader Objects!

I think that articles which are "to be continued in a future issue" have no place in a technical journal. A series of articles is fine, but each article should be complete in itself. It is particularly annoying to find references to figures which are not yet published, as in the article "Liquid Particle Behavior" by Mertes and Rhodes in the September issue.

PETER HARRIOTT

Ithaca, New York

A Nuclear Thank You!

The October issue of Chemical Engineering Progress has just come in and I want to compliment you and your staff on the very fine job you have done of summarizing the Nuclear Engineering data released at the Geneva Congress It took some real work to get this material in such a useful and concise form in a short time.

RAPHAEL KATZEN

Cincinnati, Ohio

"Atoms for Peace" Issue

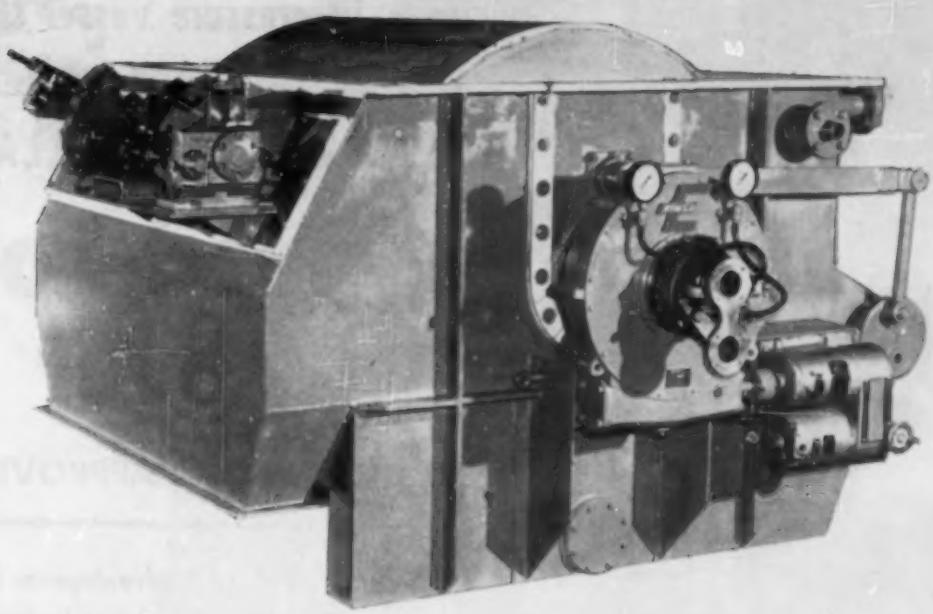
The October issue's 48-page review section was a fabulous piece of technical and editorial work . . .

Much continued success as you report the wonderful era of chemical technology that lies ahead of us.

MORRIS G. MOSES

Portsmouth, Ohio

(*Noted and Quoted, page 18*)
(*Marginal Notes, page 26*)



Absolute Purity of Product Maintained with Eimco Filters

Absolute purity of product is maintained when using Eimco continuous vacuum or pressure filters. The picture above illustrates one of the many Eimco filters being used by industries that must maintain absolute purity such as antibiotics and other pharmaceuticals, food and allied industries and chemical industries.

To meet the requirements of these industries, Eimco makes all filters to specifications produced by cooperative efforts of the customer's engineering staff and Eimco's Research and Development engineers.

The filter shown above is a high submergence type filter designed for use with precoating material. The drum is all type 316 stainless steel and the tank is of mild steel with ¼" thick PVC lining. The lining is carried out through flanged connections and bolt-on-assemblies so that the white PVC material is visible from the outside. This filter is equipped with the Eimco Hyflow automatic valve for greatest efficiency in operation and the Eimco knife advance mechanism.

All of these features are significant to the type of application for this particular filter. Your problem receives the same detailed consideration by Eimco engineers who are specialized in filtration equipment. That is the reason Eimco filters work better, last longer, produce more and require less maintenance, square foot per square foot, than any other filter.

Write for more information on your specific problem.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Tex. Birmingham, Ala. Duluth, Minn. Kellogg, Ida. Baltimore, Md. Pittsburgh, Pa. Seattle, Wash. Pasadena, Calif. Houston, Texas Vancouver, B. C. London, England Gateshead, England Paris, France Milan, Italy Johannesburg, South Africa

B-162

An entirely new concept in pressure vessel closure

SPARKLER-PASSALAQUA

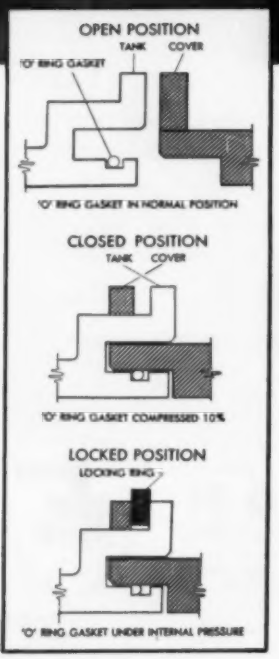
Speed-Lock Cover

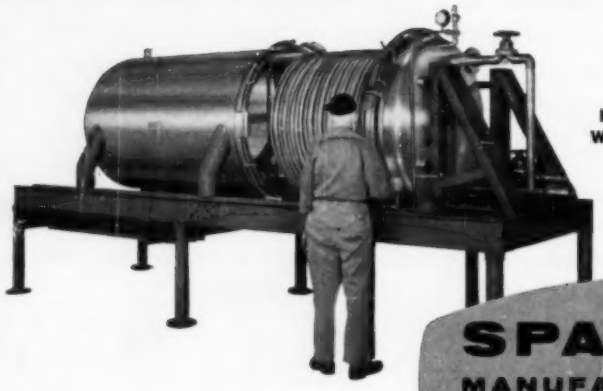
A. S. M. E. APPROVED

Now Standard on all Sparkler Model MCR Filters

With these 8 advantageous features

1. Easy to operate—can be opened and closed in seconds by hand, with your eyes shut.
2. O-ring gasket gives self-seal which becomes tighter as internal pressure increases.
3. Visible bow-shaped lugs on third ring lock cover quickly and surely.
4. Locks in both opened and closed positions.
5. All holding devices are engaged at once.
6. Stress divides itself equally among all lugs.
7. Fabricated and forged of high tensile strength steels.
8. A.S.M.E. Approved.





MODEL MCR RETRACTABLE TANK FILTER WITH SPARKLER-PASSALAQUA SPEED-LOCK COVER

SPARKLER MANUFACTURING CO.
MUNDELEIN, ILL.

Sparkler International Ltd. with plants in Canada, Holland, Italy and Australia. Service representatives in principal cities throughout the world.

Filtration engineering and manufacturing exclusively for over 30 years.

high quality product

boost average ratings as much as 2 octane numbers with the

Ljungstrom® Air Preheater

With waste heat recovered and returned to the furnace in combustion air, the most modern heat-transfer systems can be operated at peak efficiency.

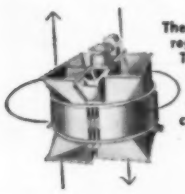
That's why you boost product quality with the Ljungstrom Air Preheater. It's heat-recovery efficiency makes possible advanced furnace designs that assure remarkably close control of processing. And finer control means a more uniform product . . . with average ratings as much as 2 octane numbers higher. One still's added income just from higher product quality is $58,000 annually.

HOW FAST IS "WRITE-OFF"?

In earnings from higher octane ratings, many refiners write off the cost of the Ljungstrom installation in less than two years. This time is cut to *nine months and even less*, when the other Ljungstrom advantages are taken into account — saves up to 20% in fuel costs . . . permits more economical furnace design, with no need for convection surfaces . . . burns many fuels you used to throw away . . . results in consistently higher through-put . . . and minimizes slag.

For more complete details on what the Ljungstrom Air Preheater can do for you . . . for an analysis of the heat recovery benefits obtainable in fuel burning equipment — call or write The Air Preheater Corporation.

Wherever You Burn Fuel, You Need Ljungstrom



The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves, the heat is transfered from the waste gases to the incoming cold air.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

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of engineering data on J-M products

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. . . provides valuable information to help you solve many design and operating problems

Here is a new handbook which can be a valuable aid to you in many ways in improving operations and lowering maintenance costs in your plant.

Whether your problem is reducing heat loss, fighting corrosion, sealing gases and liquids, controlling motion, filtering liquids, improving formulae or protecting against fire, weather and wear, this handbook will aid you in finding the solution.

This handbook contains 52 pages of useful up-to-date engineering information on Johns-Manville products used in the process industries. The answers to your thermal insulation problems may be found in the section which shows methods of calculating heat transmission. Also included are tables of heat losses from bare surfaces and equivalent thicknesses of pipe insulation. Graphs provide information on surface resistance for both pipes and flat surfaces.

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BACK IN THE 1880's

when plate glass was first commercially produced

High Pressure Autoclave

Koven

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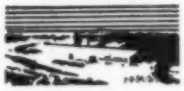
To flourish, American industry has always depended upon a careful selection of the best facilities. That's why, as far back as the early 1880's, chemical manufacturers insisted upon the use of KOVEN-built equipment—to ensure the most efficient means to fast, economical production.

Designed and built to fit specific needs, KOVEN Individualized Equipment has, for almost 75 years, contributed to the ever-increasing growth of the chemical industry. Why not let this invaluable experience work for you, too. There's no obligation—so call or write now for a consultation with a trained KOVEN representative. Send for Bulletin #550.

Bulk Storage Tank Made of Steel

Plants:

Jersey City, N. J.



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Specialists in intricate fabrication using:

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Fabrication to all A.S.M.E. Codes

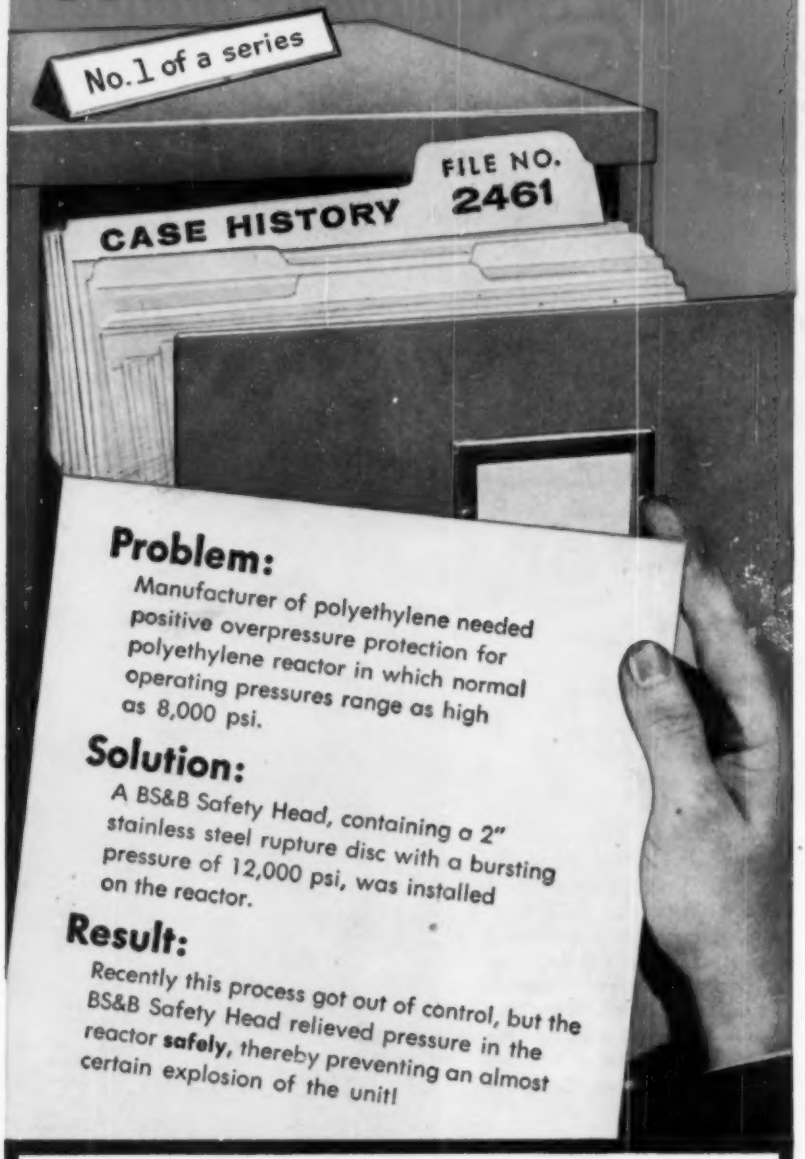
X-RAY INSPECTION FOR QUALITY CONTROL.

KOVEN equipment in all metals and alloys includes: High pressure vessels, extractors, mixers, stills, kettles, tanks, stacks, breechings. Shop and field erected storage tanks to 2 million gallons, high vacuum testing.

KOVEN FOR INDIVIDUALIZED EQUIPMENT SINCE 1881.

L. O. Koven & BRO., INC.
154-F Ogden Ave., Jersey City 7, N. J.

BS&B Safety Heads SOLVED THE PROBLEM!



Problem:

Manufacturer of polyethylene needed positive overpressure protection for polyethylene reactor in which normal operating pressures range as high as 8,000 psi.

Solution:

A BS&B Safety Head, containing a 2" stainless steel rupture disc with a bursting pressure of 12,000 psi, was installed on the reactor.

Result:

Recently this process got out of control, but the BS&B Safety Head relieved pressure in the reactor **safely**, thereby preventing an almost certain explosion of the unit!

OFFICIALLY OVER 60 YEARS RELIABILITY BS&B ANOTHER EXAMPLE OF PRODUCT LEADERSHIP

Have you considered what BS&B Safety Heads can do to improve the safety of **your** pressurized equipment? Complete information on the many possible applications of BS&B Safety Heads will be sent on request.

THE "CIRCUIT-BREAKER" of Pressured Systems

BLACK, SIVALLS & BRYSON, INC.
Safety Head Division, Dept. 2-DX12
7500 East 12th Street Kansas City 26, Missouri

NOTED AND QUOTED

Value of Engineer-Scientist Team

Engineering problems are . . . becoming more complex: the "hit and miss" solution of bygone days is no longer looked upon with favour. However, as engineering is an art, intuition, judgment, and experience will continue to play an important part not only in working out the best solution for the better known problems but, particularly so, those problems partially or wholly beyond the present engineering range of knowledge.

The engineer must play an even greater part on our world of science, where his clear thinking and leadership will help others. He cannot remain solely within the walls of his own profession. He can do much to explain to laymen, in simple language, the meaning of his work to society. While continuing to improve himself, he should keep in mind Milton's classic definition of an educated man. "I therefore call a complete and generous education, that which fits a man to perfom justly, skilfully and magnanimously all the offices both private and public of peace and war."

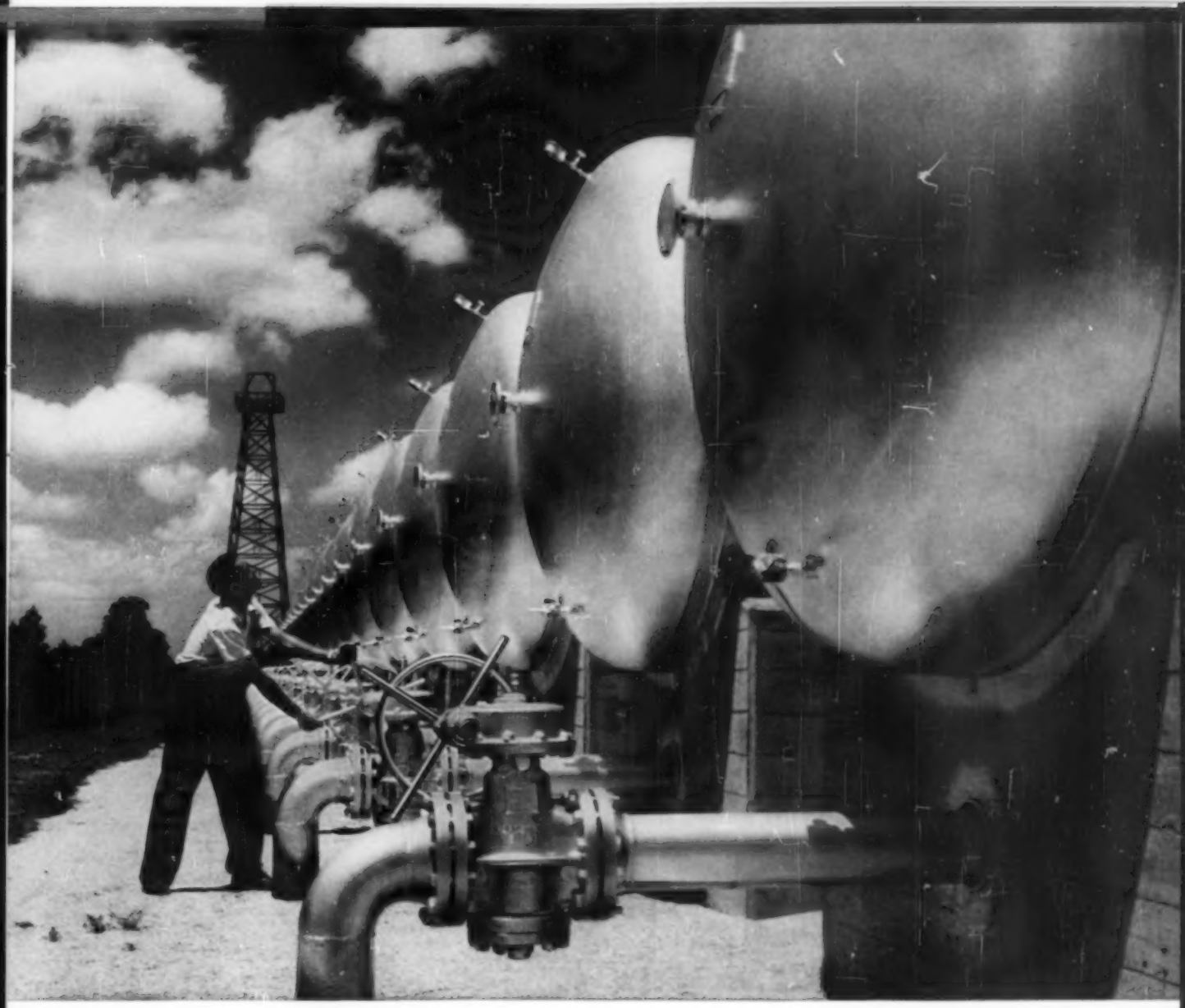
The engineer and the scientist have accomplished much, but they face a future that will challenge them beyond their wildest imagination. They are a team, and they must remain so, if they are to meet and conquer the monumental problems of the future. Not least of these problems will be their responsibility to society. Will they be equal to these responsibilities? Of course they will, but only if we, who have the future in our hands today, give them the leadership they will require.

R. E. Heartz
at Diamond Jubilee Semi-annual meeting, A.S.M.E.

Group Effort and Group Harmony

Here then is a major problem—our economy requires group effort to perform its increasingly complex tasks, it requires also individual genius and accomplishment if we are to go on to greater spiritual understanding and material well-being. The task of the administrator in government, in business, in science is to create group harmony, while at the same time encouraging high individual performance. The conquest of the atom could not have been accomplished without group effort on an enormous scale . . . The group serves

(*Continued on page 22*)



Leak Proof

Sooner or later, ordinary valves leak because they depend solely upon uncertain metal - to - metal seating. Rockwell - Nordstrom valves are leak proof because the unique Sealdport* lubrication system surrounds the plug and body with a positive seal of pressurized lubricant. This penny's worth of prevention saves countless dollars in lost product, maintenance, and down-time.

Rockwell-Nordstrom, *the original lubricated plug valve*, has set outstanding performance records for forty years. Why not specify the valve and lubricant combination that has *proved* its dependability and economy. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

*a registered trademark of Rockwell Manufacturing Company

ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF

Lubricant Seating
Controls Abrasive Slurries

Slurries and entrained solids raise havoc with ordinary valves. Erosion and corrosion soon cut into vital seating areas and ruin the metal-to-metal closure. This can't happen in Rockwell-Nordstrom valves because the seal is a constantly renewed film of tough lubricant under pressure. Seating areas are *never* exposed. And there are no pockets or cavities in the Nordstrom valve to collect deposits that ruin other valves.

The Rockwell-Nordstrom combination of the right valve and the right lubricant for every slurry service will give you a more dependable operation—at lower yearly cost—than any other valve you've ever used. Write today for full information. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

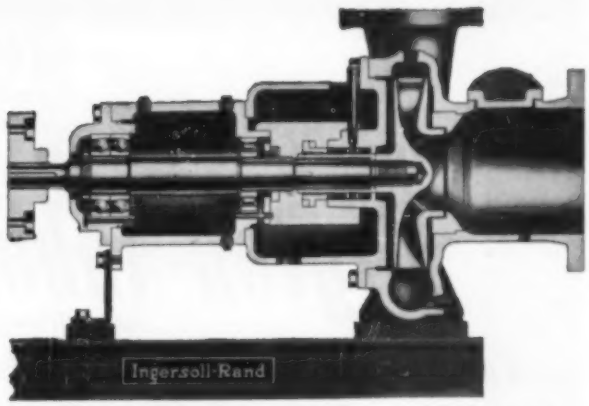
ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF

WANTED:

Your TOUGHEST Pumping Jobs!

Radically new type of centrifugal pump handles a variety of industrial liquids, even the most difficult, without clogging or air binding



Section through Class 6EH pump, showing the patented construction

Not just a modified centrifugal pump, the new Ingersoll-Rand Class EL, EM and EH Pumps feature a *radically new* and patented construction which makes them non-clogging, non-vapor-binding, self-venting and self-priming.

Foamy solutions containing up to 50 percent entrained air or gases can be pumped continuously without danger of losing prime or vapor binding. And viscous liquids or mixtures with exceptionally high solids content can be handled with equal ease—with complete freedom from clogging.

Crystals or other solids in suspension can be pumped without injury. And with *any* type of liquid, the pump will maintain its prime even when the suction piping is uncovered or exposed to the air.

Class 6EH Industrial Liquids Pump

These heretofore unattainable performance characteristics result from the unique *diverging* impeller design in which the area at the exit is much greater than at the inlet. Hence the material pumped cannot enter in sufficient quantity to replace the ejected liquid and a vacuum space is created between the blades. Unlike the ordinary centrifugal pump, conversion from velocity to pressure is accomplished in the impeller as well as the casing and the relative velocities are considerably lower. This reduces impeller wear when handling liquids with high solids content.

Field experience with the new EL, EM and EH pumps has conclusively proved their ability to handle the *toughest* pumping jobs. In actual service, they are pumping solutions that no other centrifugal pump could handle without air binding or clogging.

If *you* have a liquid moving problem that's too tough for an ordinary pump, this new I-R Pump offers a practical, low-cost solution. Sizes available for capacities from 200 to 7000 gpm, heads to 225 ft. For complete details, send today for your copy of Bulletin 7325.

Ingersoll-Rand

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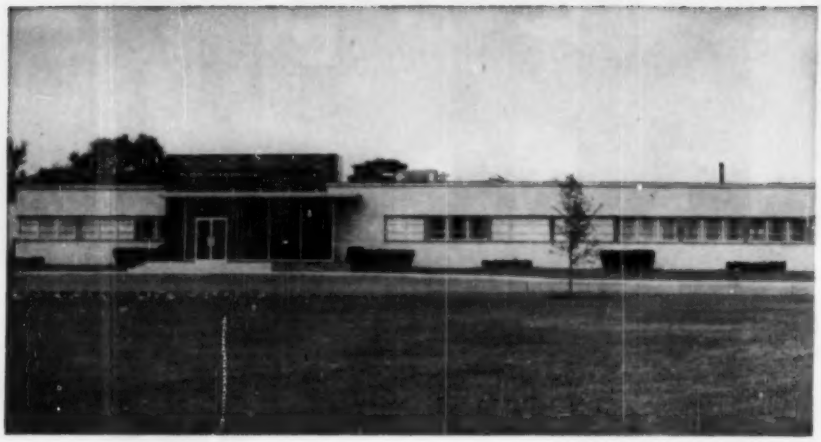

Research Laboratories
The Norwich Pharmacal Co.
Norwich, New York

LABORATORY SAMPLE FROM

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RESEARCH LABORATORIES — DESIGNED — ENGINEERED and Constructed to answer your needs and the competition of tomorrow

Research or Control laboratories are intricate feats of design. Everything must be planned, designed and equipped to produce utmost efficiency and successful results.

Wigton — Abbott Corporation has had long experience in creating and developing Research Laboratories in all fields of industry. A long list of satisfied clients will certify our proficiency in *Engineering* and *Construction.*

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Wigton-Abbott Corporation
ENGINEERS & CONSTRUCTORS
Main Office
PLAINFIELD, N. J.
WA
Est. 1924

NOTED AND QUOTED

(*Continued from page* 18)

as a powerful stimulant of ideas, but it cannot produce the flash of inspiration on which success and progress depend.

C. H. Greenewalt
"Individual Responsibility"
before National Safety Council

Engineers and the Government

The Federal Government as a unit is the largest employer of engineers in the United States. . . .

Engineers in Federal service have opportunities to participate in challenging work of vital importance. Professional engineers are employed by more than 30 Federal agencies in installations throughout the United States. Several of these provide research facilities unparalleled elsewhere, and all assist and encourage their engineers and scientists to grow and develop as fast as their native abilities permit. . . .

The Government needs more engineers in all branches of the profession, although at present the most urgently needed are electrical, mechanical, ceramic, chemical, and civil engineers. While there are many openings for experienced engineers, the greatest need is for men just entering the profession. Many Federal agencies have active recruiting programs for young engineers and have published pamphlets outlining engineering opportunities within their services. A Civil Service Commission pamphlet lists 30 such publications. Some agencies recruit engineering students to serve in trainee positions during vacations. . . .

Henry H. Armsby
in *Mechanical Engineering*

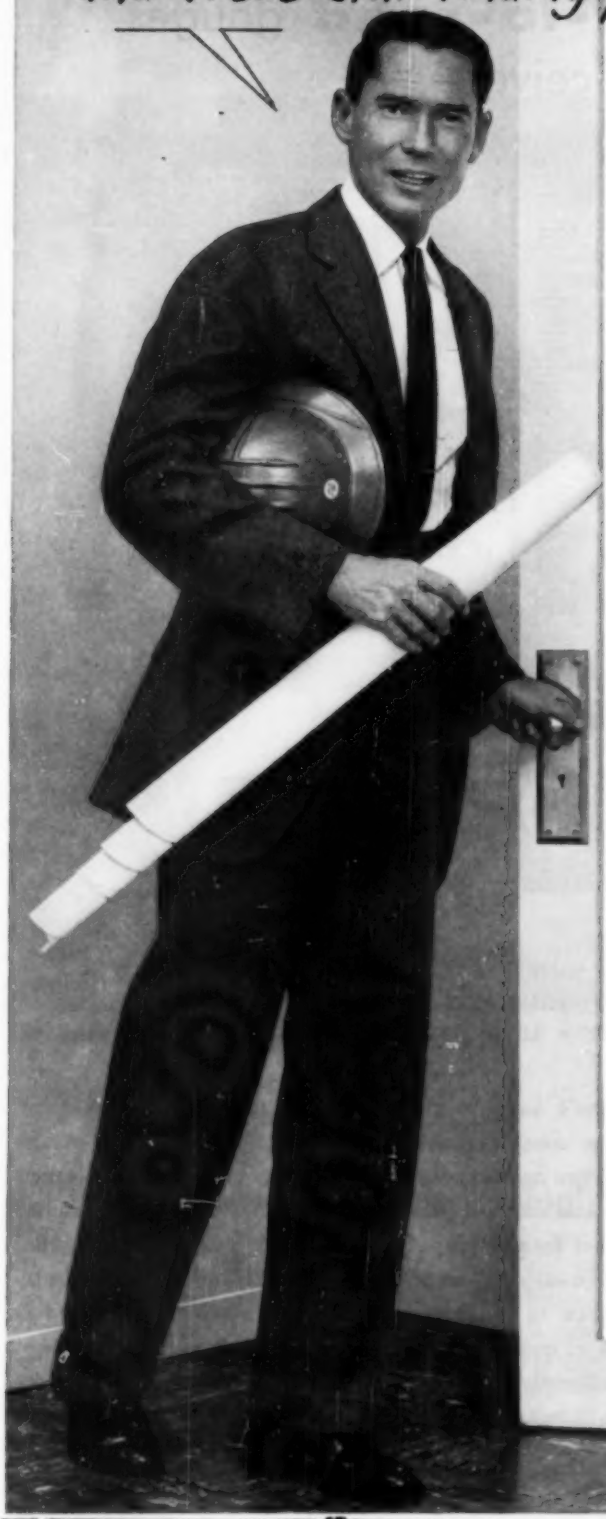
Concerted Effort—Not a Game of Chance

No uneducated person, however intelligent, has accidentally stumbled across any of the great fundamental truths . . . These great discoveries, and even smaller steps that have improved a product slightly or lowered a production cost, have only been developed by men with knowledge and training to lead them up to the discoveries and then enabled them to recognize them when they got there.

These advances in knowledge are . . . results of the combined efforts of all the men working on a problem, plus the work of all men whose previous work is available.

William C. Foster
Address at Second Annual
Observance Chemical Progress Week

We've used "KARBATE" equipment for years and we're still finding places where it pays off!



■ Many users of "Karbate" brand impervious graphite process equipment originally installed it where nothing else would work — then went on to extend its use to other, less severe, process-unit locations. A job doesn't have to be a major headache for "Karbate" equipment to pay off. *Wherever* corrosive conditions exist, consider "Karbate" impervious graphite and "National" carbon and graphite. You'll be pleased with the economies they offer.

10 PAY-OFF FEATURES OF "KARBATE" BRAND IMPERVIOUS GRAPHITE PROCESS EQUIPMENT:

- Low first cost
- *Extended* low maintenance
- Corrosion resistance
- Immunity to thermal shock
- No metallic contamination
- High thermal conductivity
- Workability — readily fabricated and serviced in the field
- Sturdy, durable constructions
- Standard stock units
- Complete technical service

Manufactured only by

NATIONAL CARBON COMPANY

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

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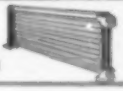
Pumps— Catalog Section S-7250

Pipe and Fittings— Catalog Section S-7000

Heat Exchangers— Catalog Sections S-6740 and S-6840



Cascade Coolers— Catalog Section S-8820

HCl Absorbers— Catalog Section S-7480

announcing a new line of **small-size easy-to-read** gauges and receivers

NEW **REPUBLIC 5 GAUGES**

Individual, Independent Measuring Units for
DRAFT • PRESSURE AND VACUUM • DIFFERENTIAL PRESSURE • TEMPERATURE
High Accuracy Receivers for Pnuematic Transmitters and Electric Meters Measuring
FLOW • PRESSURE • CO_2 • DENSITY • LIQUID LEVEL • OTHER PROCESS VARIABLES

Important Features

- FIVE INCH ILLUMINATED SCALES
- INDEPENDENT, INTERCHANGEABLE UNITS
- MULTIPLE OR INDIVIDUAL MOUNTING — from one to eight units to a single case
- EASILY MOUNTED — no panel drilling necessary in most cases
- SCALES EASILY CHANGED OR COLOR-CODED
- POINTER MOTION REVERSIBLE
- SIMPLIFIED CONNECTIONS AT BACK OF CASE
- REMOVAL FROM FRONT OR BACK

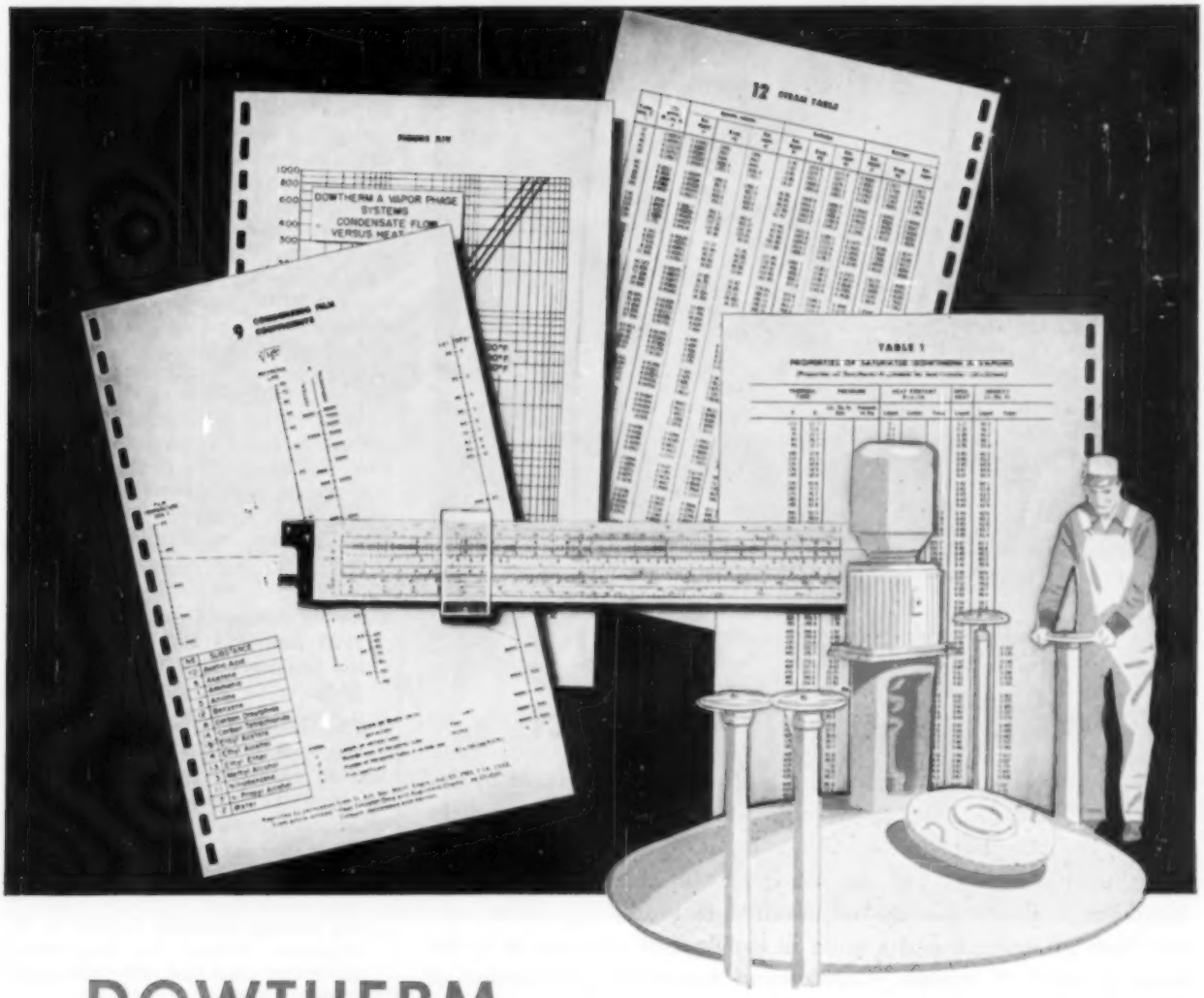
Now you don't have to sacrifice instrument performance and readability to size considerations. With Republic's new line of small-size V5 Gauges, you can save panel space, make more compact instrument groupings and *still* get the accuracy, sensitivity and readability you would expect from conventional sized instruments. Full sized diaphragms, bellows and helix units in V5 Gauges assure "big" gauge performance in an instrument that requires only one-fourth the panel space of conventional gauges. Five inch scales are almost flat and are indirectly illuminated as a standard feature for easy reading — even from a distance.

• ***Write for New V5 Bulletin*** ▶

REPUBLIC FLOW METERS CO.
2240 Diversey Pkwy., Chicago 47, Illinois

DOW

The modern concept in process heating



DOWTHERM

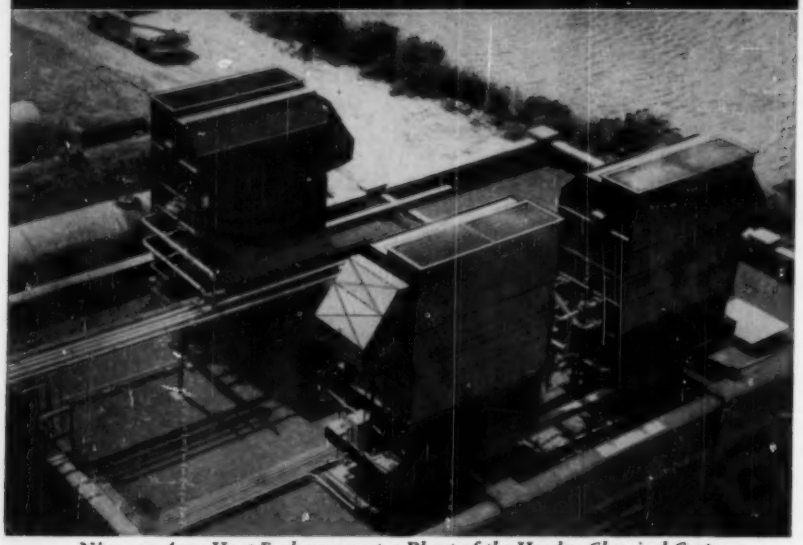
. . . ideal transfer medium for high temperature, low pressure heat

Many years ago steam provided a giant step in the history of industrial process heating. Today Dowtherm® is providing still another giant step by extending the advantages of vapor-phase heating to much higher temperatures than ever before possible. From noodles to nylon, from paint to plastics—hundreds of industries are processing with greater efficiency and lower cost through Dowtherm heat.

The important story here is pressure. Dowtherm liquids are converted to vapor just as water is converted to steam, and then the similarity ends. For steam at 700° F. exerts a pressure of 3,000 psi—but Dowtherm A at this same temperature exerts a pressure of only 95 psi! The savings in thinner-shelled, more compact equipment are obvious. Hazards in high-pressure equipment are avoided, and many designs impossible to fabricate for steam pressure are now practical. For more information on Dowtherm, the modern transfer medium, write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 728A-2.

you can depend on DOW CHEMICALS DOW

IMPROVED CONDENSING and Cooling of Reflux



Niagara Aero Heat Exchangers at a Plant of the Heyden Chemical Corp.

Get Better Control of Distillation Product

● Liquid or vapor temperatures are always held constant by the Niagara "Balanced Wet Bulb" control method of evaporatively cooling or condensing, which automatically varies the cooling effect proportionately to the load. The distillation product is therefore uniform throughout all changes in climatic conditions the year around; it is the same in the heat of summer as in the freezing cold of winter. Continuous maximum production is thus insured.

Non-condensibles are effectively separated at the condensate outlet, with notable sub-cooling after separation for greater vacuum pump efficiency.

NIAGARA AERO HEAT EXCHANGERS give sustained full capacity in cooling and condensing with no dependence on cooling water . . . eliminating problems of water supply, availability, temperature, or quality.

For full information write for Bulletin 120

NIAGARA BLOWER COMPANY

Over 35 Years of Service in Industrial Air Engineering

Dept. E.P., 405 Lexington Ave. New York 17, N. Y.

District Engineers in Principal Cities of U. S. and Canada

MARGINAL NOTES

Chemical Engineering Cost Estimation. Robert S. Aries and Robert D. Newton. McGraw-Hill Book Company (1955), $6.00.

Reviewed by Charles E. Dryden, Ohio State University, Columbus, Ohio.

An engineer who can make a reliable cost estimate is a valuable asset to management. Aries and Newton have prepared their book for the express purpose of showing how this can be done. It serves excellently as a handbook in this field; as such it contains a large variety of raw-material and equipment costs adjusted to the 1954 price level. Typical work sheets and equations for all phases of cost estimating are given with ample discussion. References can be found at the end of each of the ten chapters.

It might have been better to place the last chapter in the book at the beginning to introduce the importance of economic evaluation and the reason for making cost estimates. This does not in any way detract from the usefulness of the work which should be purchased by every engineer who makes cost estimates.

Code for Pressure Piping. ASA B31.1–1955 American Society of Mechanical Engineers, New York, 137 pages. $4.00.

The booklet includes sections on power, industrial gas and air, refinery and oil transportation, district heating, refrigeration, fabrication details, materials, and appendix.

Review of Current Research and Directory of Member Institutions. Engineering College Research Council of the American Society for Engineering Education, New York, XII+ 352 pages (1955), $2.00.

This booklet, primarily useful as a guide, should be a source of information and inspiration to the engineering colleges. Also, according to Harold K. Work, chairman, Engineering College Research Council, it should aid students in determining where to receive the education most suited to their life plans. A study of the contents of this work indicates that our engineering colleges are serving both as a source and disseminator of information. Approximately 7,500 research projects are reported with the number of people engaged in these research projects numbering 15,000 comprising faculty, graduate students, and research engineers. Research expenditures approxi-

(*Continued on page 28*)

Choosing a stainless steel supplier is like choosing a friend; all else appearing equal, the intangibles of service and reputation stand out. Many users of stainless steel turn to B&W because they know B&W's reputation for quality and service, and because they know that B&W controls every step in the tube-making operation from pouring the stainless ingot to carefully inspecting the finished stainless tube. Because B&W quality control more than satisfies all customer and code requirements, every buyer of B&W stainless steel tubes is assured of manufacturing skill, uniformity and close tolerances in every foot of stainless tubing he acquires, and quick service via a nationwide network of B&W stainless tubing distributors.

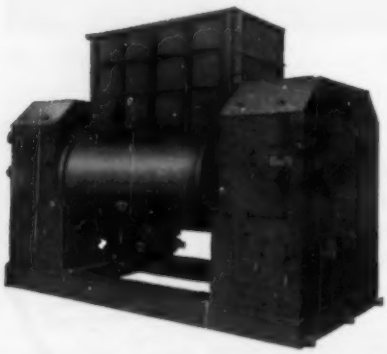
Take a tip from the experience of thousands in the process industries, as well as architects, designers, fabricators and finishers, and get in touch with Mr. Tubes, your link to B&W, for a detailed story of the advantages of B&W stainless tubing and how you can get more for your money with stainless. *Or write for Bulletin TB 355 CEP.*

B&W
TUBULAR PRODUCTS DIVISION

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION
Beaver Falls, Pa. and Milwaukee, Wis.: Seamless Tubing, Welded Stainless Steel Tubing
Alliance, Ohio: Welded Carbon Steel Tubing
Milwaukee, Wis.: Seamless Welding Fittings

TA-5036(P)

READCO'S IMPROVED MIXER DESIGN PROVIDES COMPLETE DISPERSION IN LESS TIME...FOR LESS COST



It's Readco's unique split-level dispersion bowl that makes the difference. It provides a greater ratio of surface to the volume of mix. Overlapping sigma arm mixing action exposes new surfaces and breaks down the entire mass with each rotation, producing a homogenous mix in a short mixing cycle, eliminating peak loads. Closer clearances between mixer arms and shell prevent build-up of materials.

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MARGINAL NOTES

(Continued from page 26)

mated $75,000,000 annually for all branches of engineering and most related fields.

Solar Energy Research. Farrington Daniels and John A. Duffie. University of Wisconsin Press, Madison (1955), $4.00

Reviewed by Barnett F. Dodge, Chemical Engineering Department, Yale University, New Haven, Connecticut.

This book is based on a comprehensive symposium on all phases of the utilization of solar energy which was held in Madison in September, 1953. There are thirty-one contributors, each an expert in some phase of solar energy research or in a related field having an important bearing on the general subject of solar energy. The range of topics covered is shown by the following listing of the titles of the eleven sections:

- I Expected World Energy
- II The Nature and Availability of Solar Energy
- III Space Heating and Domestic Uses of Solar Energy
- IV Solar Power
- V Solar Evaporation and Distillation
- VI Atmospheric Phenomena, and Conversion of Solar to Electrical Energy
- VII Solar Furnaces
- VIII Photosynthetic Utilization of Solar Energy
- IX Photochemical Utilization of Solar Energy
- X A British Viewpoint
- XI Miscellaneous Applications of Solar Energy and Suggestions for Further Research

At the end of the book there is included a bibliography first on the general subject and then special ones for each section of the book.

Besides furnishing the worker in this field with good reviews of the recent developments, the book is good general reading for any scientist or engineer who wishes to keep informed on one of the most interesting developments of our times.

Books Received

Laplace Transforms for Electrical Engineers. B. J. Starkey. Philosophical Library, New York (1955), 279 pages, $10.00.

Magnetic Materials in the Electrical Industry. P. R. Bardell. Philosophical Library, New York (1955), 288 pages, $10.00.

Fifth Symposium (International) on Combustion, Combustion in Engines and Combustion Kinetics. Reinhold Publishing Corp., New York, 802 pages, $15.00. Published for the Combustion Institute under auspices of The Standing Committee on Combustion Symposia, Bernard Lewis, Chairman, (1955).

COOPER ALLOY CORPORATION BRIEFS

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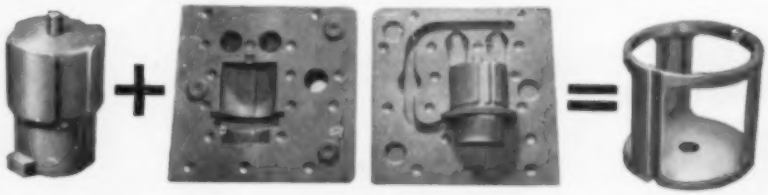
Valve buyers and users will be glad to know that we've put in a new stock of this popular booklet "75 Questions" which consists of information revealed at Cooper Alloy Valve Clinics. The questions cover materials, operations, service problems, installations and repair of stainless steel valves. They originally appeared as *continued bottom col. 2*

CASTING INSTRUMENT HOUSING



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'OLE MAN RIVER

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75 QUESTIONS *continued*

a feature article in a leading Chemical publication, and are designed for fast reading and easy reference. Copies available on request.

The unprecedented demand for our new stainless steel valve and fitting catalog has been welcome but embarrasing. In an attempt to assign each catalog, properly register it, deliver it in person so as to explain the various forms in which it is available and advise our representatives and distributors so that catalogs in the field can be kept up to date, our office staff has been working round the clock and is still falling behind. If you're one of those whose request has gone unanswered, please bear with us. We're doing our best to catch up.

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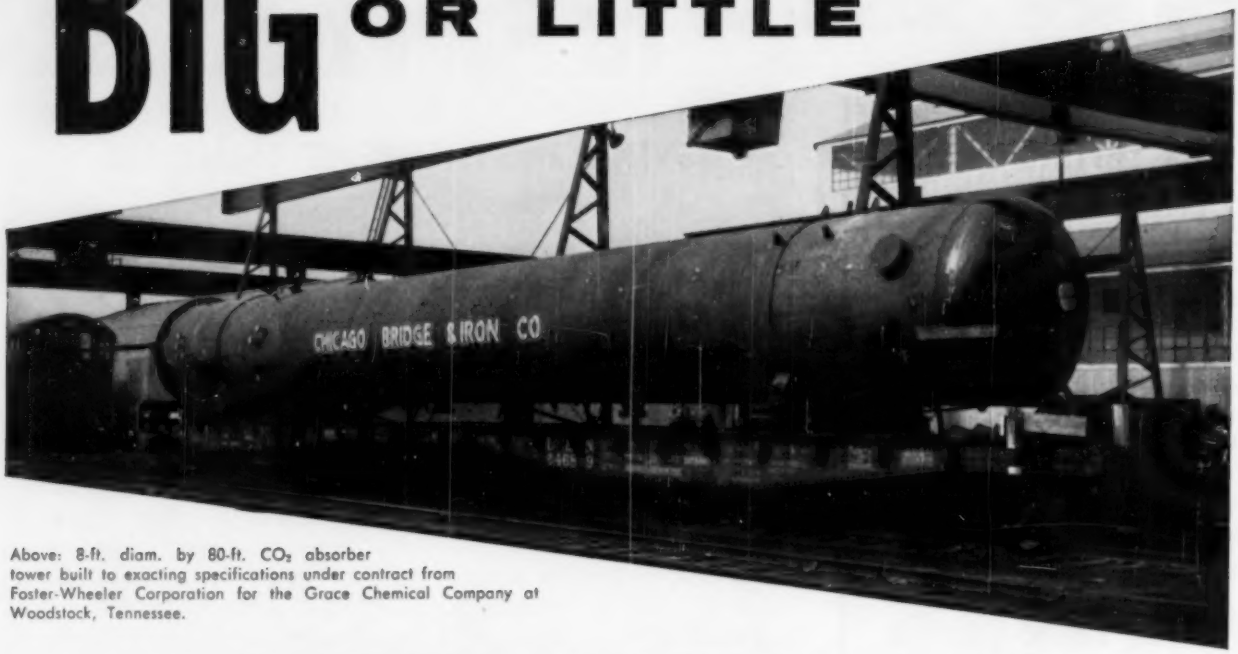
STAINLESS ENGINEERING AND MACHINE WORKS DIVISION · AIRCRAFT PRODUCTS DIVISION

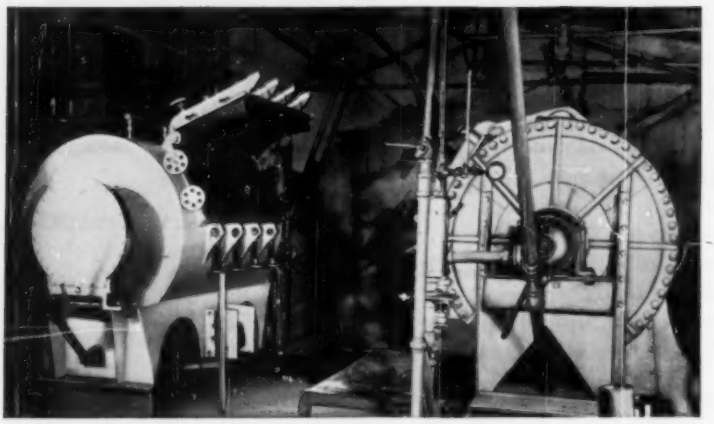
Bernard Lewis, Chairman, (1955).

BIG OR LITTLE



Above: 8-ft. diam. by 80-ft. CO_2 absorber tower built to exacting specifications under contract from Foster-Wheeler Corporation for the Grace Chemical Company at Woodstock, Tennessee.

it's equipment that makes a profit!



Right: Conkey Rotary Leaf Pressure Filters separating coal resins and solvents.

Processing equipment can cost you money . . . in down time, repairs and lost production. Only the best is good enough . . . and from towers to filters CB&I can build *you* the best.

Chicago Bridge & Iron Company is a specialist . . . in experience, ability and facilities. They are equipped to design, engineer, fabricate and erect structures such as the 8-ft. diam. by 80-ft. CO_2 absorber tower or Conkey Rotary Leaf Pressure Filters shown here.

CB&I's four strategically located plants have skilled engineers and workmen and the facilities to provide you with the best when your requirements are the greatest. Write our nearest office for further information.

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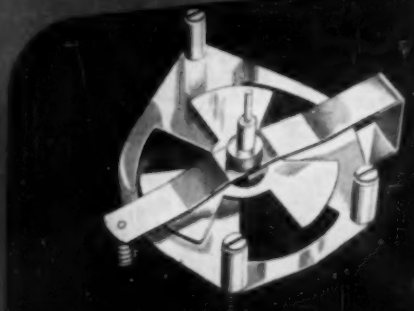

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- no gears, cables, etc.
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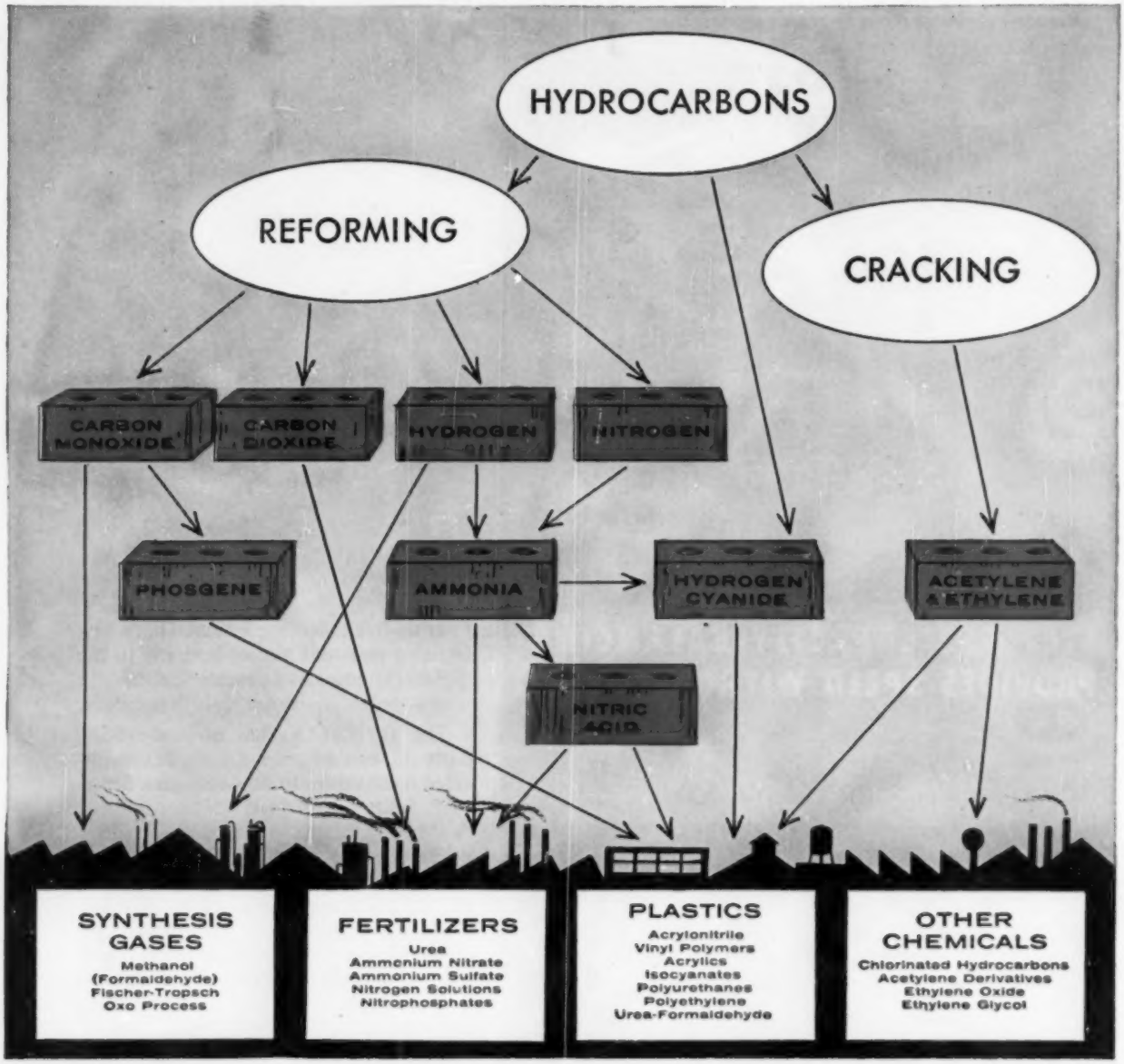

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Girdler assumes responsibility for designing, engineering and construction of process plants for these synthesis gases . . . and many other products. Take advantage of Girdler's vast experience when you *start* to plan your processing facilities!

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CEP trends / DO FACILITIES-COSTS AFFECT EXPANSION?

At this time of year chemical executives start going over their budgets, counting up their treasury cash, and conferring with research directors to figure out plans for more plant expansion. They look at Federal reserve bank policies, at the prices of the materials they must buy and at the trends in the policies of labor unions, as well as the future demands of their own industry.

There are always risks involved in the allotment of many millions for new plant capacity—new capacity that cannot be running for another year and a half or two years from now—when no one, even the most expert economists, can be sure what business conditions will prevail. But the planning must be done and new ventures must be undertaken.

Investment Risk

Talks with the men who are doing this budgeting indicate that they are now no more concerned than they are normally about the effects of decisions having to do with going ahead on new projects. The risk of investment in new plant capacity appears to be no greater and no less than it appeared during the post war years, when major chemical expansion took place. Of course one strong incentive to this post-war building boom was the fast amortization provided by government certificates of necessity, which meant in effect that plant could be partly paid for out of funds that would otherwise have gone to pay excess profits taxes. This meant that if one firm decided to build a plant, its competitors would often feel impelled to do the same thing, so as not to be left behind in acquiring plants that would beyond the expiration of the five year write-off period require no depreciation, and therefore experience lower total costs.

It now appears that after a slight let-down in plant expenditures by some firms during 1955, a number of leading firms will spend more money in 1956. The uncertainties of an election year seem to have little effect on budgeting for more capacity.

Postponement or Plunge?

Industry seems to have become reconciled to the idea that a gradual but continuous inflation in the cost of labor . . . and therefore of materials and of construction . . . is going on. There is thus little to be gained by postponing projects in the hope that next year or the year after might bring lower costs. Firms that postponed work over the past five years found that costs were even higher when they finally decided to go ahead.

One factor is the evidence of a creeping up in the price of chemical equipment, sparked by the scarcity and the higher cost of steel. One chemical buyer estimates that equipment now costs in the range of 5% to 10% over a year ago. There is indication also that labor is getting restless again, not only in the chemical industry but in other industries which supply the chemical industry with its needs for new capacity. All of this means that sound projects should not be postponed.

One firm that cut its budget in 1955 about 35% below the 1954 level, plans to more or less double expenditures for 1956 and 1957. This is for projects which it is believed will pay off in a reasonably short period.

A larger firm also expects to increase its expenditures next year over the 1955 budget. This firm takes the position that an inflation in plant building costs of about 3% to 5% a year can be counted on. As one executive puts it, "there is only one way in building costs and that is up."

An executive of another of the larger firms in the chemical industry comments, "We expect to go ahead with expansion on a normal basis and see nothing in the picture to change our plans." This company also plans somewhat larger expenditures next year than in 1955. The belief at upper management levels is that the prospects are good that construction costs will move ahead next year and might rise as much as 10% in the next two years.

A heavy chemicals manufacturer which has not undertaken major expansion for years finds its competitive market position demanding enlargement of productive capacity in spite of a not-too-attractive expected economic short-range return. Consequently, the firm has decided to embark during 1956 on a major program in order to maintain its position of market leadership.

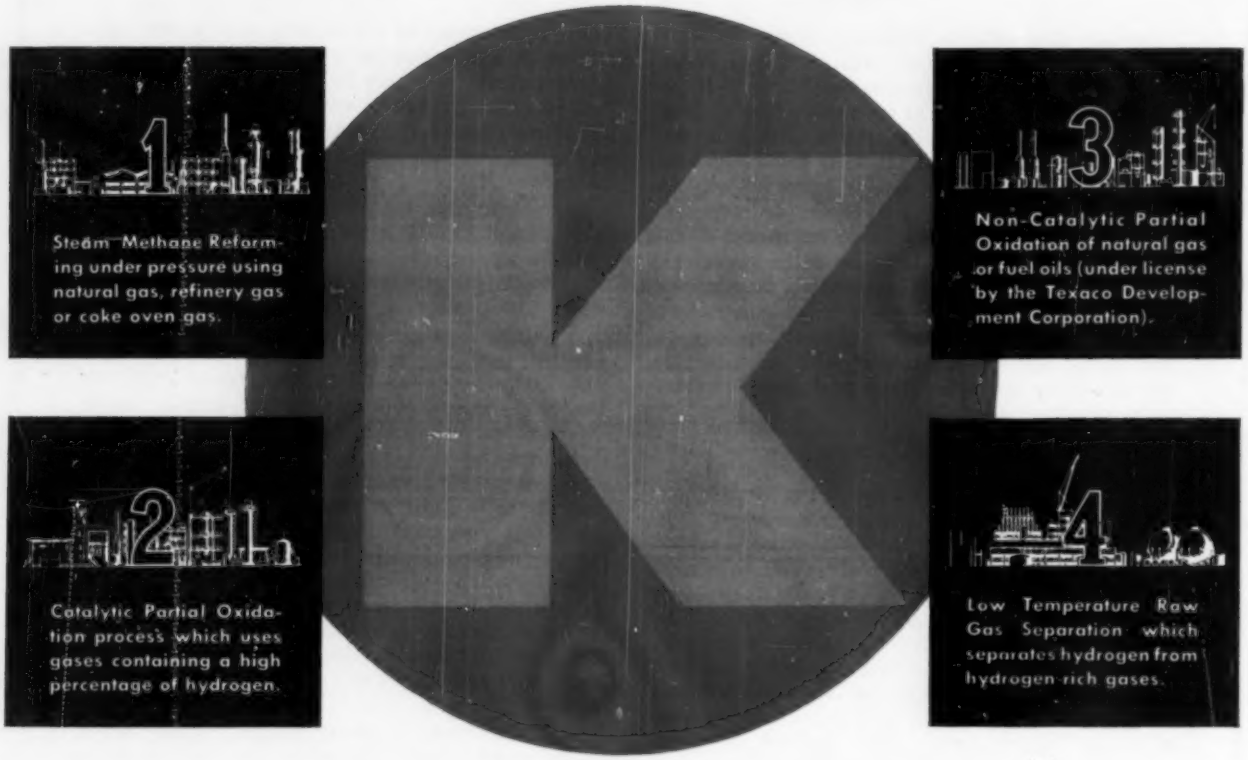
Another firm, one of the largest, does not consider present levels of facilities costs as being a controlling factor. This firm is going ahead with expansion at a level somewhat above 1955, on the grounds that market opportunities and expected return on investment justify such.

Still another firm, limited to petrochemicals, is building a new plant for a product that might have been made in one of the synthetic rubber program plants disposed of recently by the government at a depreciated value. This firm evidently believes it is better off building anew, citing technologic advances to be incorporated in the new facility as providing the advantage to assure a strongly competitive position.

Long-range Planning

For the last five years the chemical industry has been adding a total of about $1 billion yearly for new facilities. Prospects are that expenditures for 1956 and probably for 1957 will be at around the same levels. Four of the larger companies alone plan expenditures of around $350 million for 1956.

The Best Choice of Ammonia Processes


1
Steam Methane Reforming under pressure using natural gas, refinery gas or coke oven gas.
3
Non-Catalytic Partial Oxidation of natural gas or fuel oils (under license by the Texaco Development Corporation).
2
Catalytic Partial Oxidation process which uses gases containing a high percentage of hydrogen.
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Low Temperature Raw Gas Separation which separates hydrogen from hydrogen-rich gases.

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The M. W. Kellogg Company offers four different processes, outlined above, for the generation and purification of ammonia synthesis gas. The conversion phase in all uses the Kellogg-developed, quench-type reactor. With these four basic plant types, potential ammonia producers can be sure of a design which gives optimum results under practically any local operating conditions, including power and fuel as well as feed materials.

This flexibility in ammonia plant design is the result of M. W. Kellogg's many years of successful experience in engineering petroleum refineries and petrochemical plants for major producers both in the United States and abroad. For chemical manufacturers and refiners contemplating product improvement or diversification, it is a guarantee of low initial plant cost, high productive yield, and minimum operational costs.

Details of M. W. Kellogg's four basic types of ammonia plants are contained in a recent 12-page booklet, available on request.

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CHEMICAL PROCESS DIVISION

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CEP

opinion and comment

THE $600 QUESTION

Every once in a while someone drops by the Institute offices with word of a project or idea of particular interest. Recently, it was Ken O. Beatty, Jr. of North Carolina State College, who told of the financial problem our educational institutions face. Beatty is organizing a Sunday afternoon symposium on this subject for the New Orleans meeting.

Beatty and his associates believe that we can expect sharply increasing enrollment of undergraduates, to the point that within five years we may be grasping at straws to find teachers.

Why not, one might ask, resolve this by simply increasing enrollment in graduate schools? The answer, according to Beatty, is not easy, inasmuch as he feels it will take measures beyond the means of our present methods to bring about such an increase.

The student currently approaching his B.S. degree is living in what Beatty calls a "time paradox." In this, anything which stands in the way of his getting into the presently available good-paying job looms as a serious deterrent. Such factors as military service, or years added to graduate studies merely for earning financial support, are regarded as real deterrents.

Just solve this financial-support problem for graduate students (to enable them to complete their doctorate in three years), says Beatty, and there'll be enough Ph.D's to handle both industry's needs and the bigger teaching load.

To do this, Beatty and his associates propose to enlist direct financial contributions from industry—on a larger scale dollar-wise than heretofore. Now, just stepping up the tempo over our present fellowship system will not do—according to these men.

Beatty has a plan which he calls "Fort ight Consolidated" which he thinks will work very well for both industry and the schools.

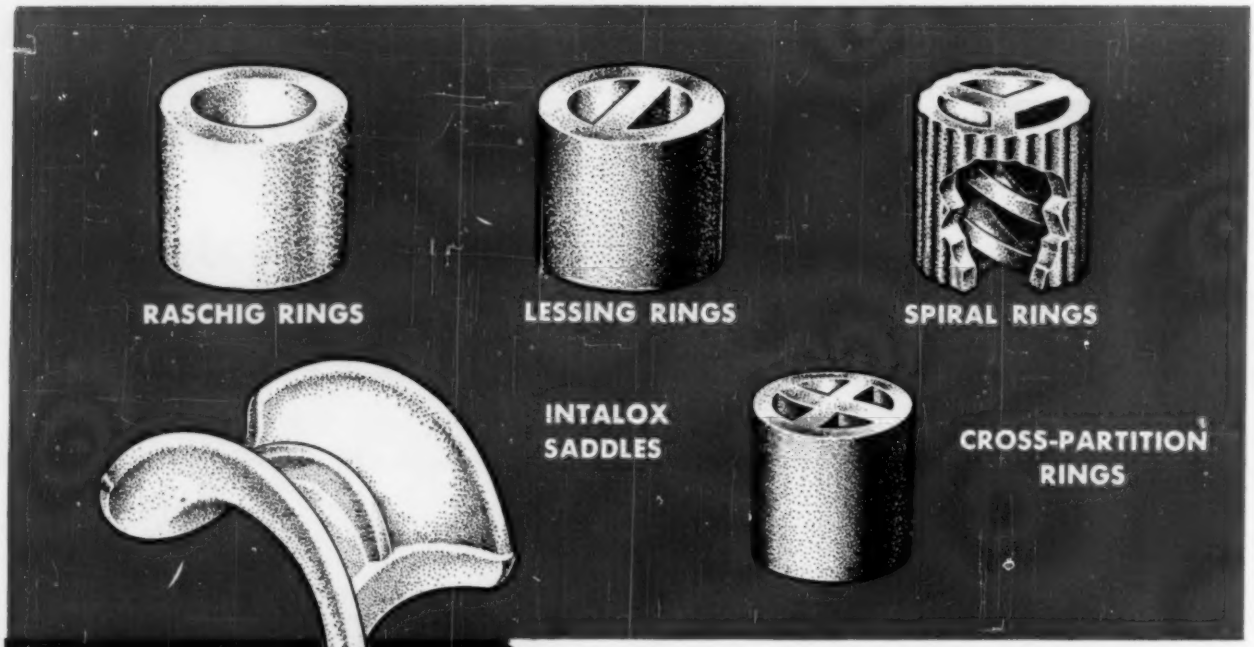
This involves the "sale" by the school of $600 shares in graduate student support. Four shares would take care of one student for a year. One share would be sold, per year, to each firm regardless of size, the idea being to distribute the sense of participation among the widest number.

Subscribers would not determine for what research the money would be used, but would receive theses and have a chance to get in an extra-early recruiting visit.

A school would sell 100 shares each year to take care of 25 graduate students—which Beatty believes can be done. An advantage to larger firms would be to provide a means for distributing their funds among a large number of schools.

Whether this or some other plan might be best, is expected to receive thorough ventilation at New Orleans. The many unusual aspects of this session suggest the advisability of close attention to it by all.

J.B.M.



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Low initial cost. Most widely used of all tower packings. Made in chemical porcelain, chemical stoneware, carbon, steel and other alloys. Size range from ¼" to as high as 6", depending upon material. Sizes up to 2" are generally dumped. Larger sizes, stacked.

LESSING RINGS
A modification of the Raschig Ring. The ring has a single partition or web added to the inside. Made in 1", 1¼", 1½" and 2" sizes in chemical porcelain or chemical stoneware. Usually dumped.

CROSS-PARTITION RINGS
A further modification of the Raschig Ring. Two inside webs cross each other at right angles to create a "4-cell" ring. Cross-Partition rings are made in 3", 4" and 6" sizes in chemical stoneware. They are usually stacked in the tower.

SPIRAL RINGS
Made in single, double or triple spiral types. The function of the spirals is to increase the turbulence of the gas stream. Made in chemical stoneware in 3¼", 4" and 6" sizes. Spiral rings are used in stacked beds.

All U. S. Stoneware ceramic tower packings are made from bodies especially developed for tower service. They are extremely tough, possess high resistance to spalling and exceptional corrosion-resistant properties. Chemical porcelain bodies are completely iron-free and are of zero porosity.

CH-D

The U. S. STONEWARE Co.
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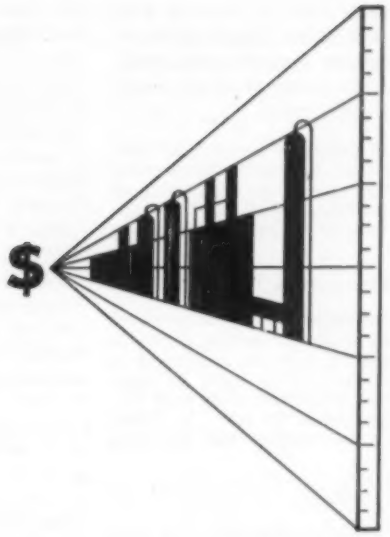
An easy-to-use yardstick which enables management to evaluate the attractiveness of chemical ventures



the venture worth method for economic balances IN CHEMICAL ENGINEERING

John Happel | College of Engineering, New York University

The term *economic balance* as generally applied in chemical engineering has to do with determining conditions which will give a maximum financial return from manufacturing operations (*6*). Often, too many intangibles are involved to allow exact analysis, in which case judgment must be intuitive. Often enough, however, such calculations cover useful phases of chemical processing with a sufficient degree of exactness. It is the purpose of this paper to present a concise method for applying certain general principles to the problem of a satisfactory financial return on a chemical engineering investment.

Concern with maximum financial return implies, of course, the primary goal of a company is profit. Actually, there may be other objectives of a strategic nature–to maintain or increase a competitive position, to increase growth in sales volume or in the number of employees, to build up a reputation (*3*). Even in such cases it is still important to determine the effect of these policies on profit.

Information Needed to Make an Evaluation

Basic information needed to make a decision on investment includes the following:

1. Effect of the investment on gross income

Gross income R, refers to yearly earnings from a venture throughout its operating life. It is equal to sales realization S, less raw materials costs, operating expenses, maintenance, social security, and unemployment taxes. It does not include deductions for depreciation and income tax.

2. Capital invested in facilities, working capital

The total capital invested consists of that actually expended for facilities (that invested in process plant) I, as well as that invested in a fund to be used as working capital, I_w. Working capital is that money which will be available for raw material inventories, intermediate and finished-product inventories, accounts receivable, and cash required to operate the project. Capital invested in offsite facilities such as utilities may or may not be included as facility capital I, depending on accounting procedure.

3. Anticipated income tax rate

Tax rates may vary somewhat from one organization to another depending on allowances for depletion of mines and natural resources. State income tax rates may be taken at an average of 3%. The new permanent Federal Tax Code (Internal Revenue Code of 1954) provides for an income tax rate of 47% for companies making a profit of over $25,000/yr. However, subsequent postponements have been enacted, so that the present rate is still 52%.

4. Allowable depreciation for accounting and income tax

Depreciation generally consists of a fixed annual charge on facility investment which will result in recovery of the initial investment at the end of the useful life of the facility. Essentially, it involves two main influences: first, deterioration, which relates to physical wear; and second, obsolescence, which relates to the extent to which equipment is up to date. Since these two influences do not run concurrently in any given case, the one which operates at the faster rate governs.

If the actual life of a plant is known, the exact rate of depreciation can be established by means of a series of uniform payments the sum of which at compound interest just equals the investment. The interest rate to be employed in economic studies is generally somewhat higher than that corresponding to the current rate for borrowing capital.

For tax purposes interest is usually not considered. In addition in cases of certified emergency defense facilities of uncertain long-time usefulness, Certificates of Necessity have been issued by the Government. These certificates permit investment on specified portions of a plant to be depreciated over a shorter period of time than would correspond to probable useful life.

5. Minimum attractive return rate

The minimum acceptable return rate i must be one which is consistent with the company's present rate of return on invested capital. New projects which have been developed to the point of technologically sound designs should show at least this rate of return.

Taking the Time Element Into Consideration

In order to allow for differences in actual plant life and that allowed for tax purposes and in general to compare ventures with different lives or with variations in return during operating life, it is necessary to convert rates of return to a common time basis for comparison. Usually the beginning of ventures is the

most satisfactory time for projects with different ending times. Explanations of compound interest formulas are available (*4, 9*), hence only those necessary here will be briefly noted.

If a sum of money is invested at compound interest at a rate i, compounded annually for n years, the total value at the end of this period is found by multiplying the investment by the following factor:

$$\text{compound interest factor} = (1+i)^n \quad (1)$$

To determine the total assets accumulated at the end of a similar period in which, instead of starting with an investment at the beginning, there is a series of equal payments at the end of each year, each payment being invested at the rate i, as before, it is possible to compute the following expression:

$$\text{future worth factor} = \frac{(1+i)^n - 1}{i} \quad (2)$$

This factor when multiplied by the value of one annual contribution gives the total assets at the end of the period in question. Conversely, if one has a sum at the end of a period and wishes to determine the amount of each annual payment, which when summed up will total the given sum, the reciprocal of the above is employed.

$$\text{sinking fund factor} = \frac{i}{(1+i)^n - 1} \quad (3)$$

If instead of the future worth, one wants to determine the present worth of the uniform series of payments, it is clear that Equation (*2*) must be divided by Equation (1):

$$\text{present worth factor} = \frac{(1+i)^n - 1}{i(1+i)^n} \quad (4)$$

Alternatively if one wishes to determine the annual charge required to recover a given investment plus interest in n years at i per cent compound interest, the reciprocal of (4) is employed:

$$\text{interest and amortization factor} = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (5)$$

Venture Worth Concept

With the above information it is possible to develop an index of project attractiveness (See development on next page).

Useful Additions to the Method

Judging the attractiveness of ventures on the basis of venture worth assumes in effect that unlimited funds are available at the minimum acceptable return rate i. In some cases, for example the selection of a number of projects for further commercial development by an organization, the total funds immediately available will be fixed by budget limitation. The optimum selection will still be that which maximizes venture profit or venture worth but with the additional restriction of a fixed maximum $I + I_w$ for the sum of capital invested.

In general the combination of projects most attractive must be selected by trial and error. However, if the relative size of each individual project is small with respect to the total available funds, it will be possible to invest close to the maximum $I + I_w$ for any selection of combinations. In such a case projects will be approved in order of their respective per cent or fraction of venture profit V or worth W of corresponding individual $I + I_w$. In the case of a non-uniform series, application of the interest and amortization factor enables one to obtain an equivalent fractional return per year. The following formulas apply:

$$v = \frac{V}{I + I_w} = \frac{W}{I + I_w}\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \quad (16)$$

Use of the above formulas is analogous to computing the attractiveness of investment in securities, where one obtains a given per cent return on an initial investment and, at the end of the period of investment, recovers the amount of his original investment. If individual projects differing in period of useful life or investment are to be compared, the use of Equation (8) is perhaps a more proper method of comparison rather than employment of a rate such as v.

Dean (*3*) has proposed the use of a slightly different method for obtaining a fractional rate of return per year from that given in Equation (16). Since this method appears to be widely used, it will be summarized here and briefly discussed. Essentially the method consists in finding the interest rate which discounts future earnings of a project down to a present value equal to the original investment $(I + I_w)$. In terms of the development in this paper, it would involve essentially the trial-and-error solution of Equation (8) for a value of i which in any given specific case would make $W = 0$, also assuming that $t = 0$, (i.e., before taxes). It is proposed that the rate of return computed by this method be compared with the company's combined cost of capital to determine the proper rate of cutoff on undesirable proposals, i.e., the minimum acceptable profitability of a proposal. Thus Dean's method requires similar information as the system proposed in the present article.

However, in order to make the incremental present worth $W = 0$, it is necessary to employ an interest rate somewhat higher than the minimum acceptable return rate. In effect this amounts to the assumption that as earnings accumulate they will be reinvested at the same rate as the annual rate of accumulation in the proposed new venture. Actually as profits are obtained they are more likely to be reinvested in propositions which for the most part will earn at a rate close to the current average rate of earnings on invested capital. Any system for the determination of the time value of a series of payments must in effect take into account how funds as they accumulate will be reinvested, whether it summarizes the over-all result as a present worth or future worth. The method proposed in Equation (16) in effect evaluates the present worth in terms of withdrawal of funds from current business operations.

Where long periods of life are involved little error will result from the employment of capitalized cost to convert a uniform annual series to present worth. Capitalized cost is simply the present worth of perpetual service, obtained by dividing annual cost by interest rate i. Use of this method for large values of n is equivalent to the following approximation for the interest and amortization factor, Equation (5):

$$i \cong \frac{i(1+i)^n}{(1+i)^n - 1}; \qquad n \to \infty \quad (17)$$

Another useful approximation for the interest and amortization factor when $n = 5$ to 20 yr. and $i = 0.05$ to 0.15 is the following:

$$0.65\, i + \frac{1}{n} \cong \frac{i(1+i)^n}{(1+i)^n - 1} \quad (18)$$

This relationship is similar to those previously proposed (*4, 13*). A general method for its derivation has been set in type and is available from the author.

Complications arise upon comparing the attractiveness of projects when the risk of the ventures involved (*5, 7, 13*) is different from that current for the industry or company. Such situations are encountered in the expenditure of money for research and development. Here the probability of success, though often not available as an exact number, is much less than in the case of projects technically proven by full-scale tests. Often, in fact, it is desirable to move ahead to full-scale operations on projects not completely proven technically in order to get into production ahead of competition. In such cases the following procedure may be employed. First calculate the venture worth W of the project on the assumption that it will be a complete success and multiply by a factor y, expressing the probability of success as a fraction. Then calculate the venture worth W based on the assumption that it will be a complete failure and multiply by the probability of failure $(1 - y)$. Add the results of these two calculations to determine the most probable value of the venture worth. If Equation (8) is employed to compute venture worth for complete

HOW TO CALCULATE AND EVALUATE VENTURE PROFIT

The basic assumption made in this derivation is that attractiveness of one venture as compared with others is measured by total incremental return above a rate i currently being obtained for the same general type of project (*6*).

The incremental return each year is designated as venture profit V. It is expressed as in Equations (6) or (7).

The gross return R and rate of depreciation for tax purposes d may change during the life of an enterprise. In this case the series of annual payments represented by V_k for each year must be summed to obtain their present worth, here designated as venture worth W in order to avoid confusion with the general employment with the term present worth in compound interest terminology. In the case of R the subscript k varies from 1 to n years, the life of the plant. In the case of d the subscript k varies from 1 to r years, the period during which the plant is depreciated for tax purposes. Thus if R_k and d_k denote gross return and depreciation for tax purposes respectively at the k'th year, W (present worth of venture profit) is expressed as in Equation (8). Deai (*2*) and Winn (*13*) have derived relationships similar to Equation (8). Note that the terms in Equation (8), except those containing R_k and d_k, are simply multiplied by the present worth factor to obtain their contributions to W. If R_k and d_k vary in some simple systematic fashion, it is possible to develop formulas for the summations indicated in Equation (8).

Borrowing a phrase from William James, one may think of W as the "cash value of an idea." It represents a sum of money above the initial value of the proposed investment equivalent to the profit which will accrue during the entire plant life. Future annual profits are discounted at an interest rate equal to the minimum acceptable return rate for the type of venture in question. In effect this assumes that as they are obtained profits will be reinvested in the business at the rate of return which is current for the over-all investments of the company considering the proposed new venture. New propositions thus may be looked upon as "incremental" in the sense that the existing business is as the yardstick of their attractiveness. Mathematically, one might be said to use the method of perturbation to arrive at the effect due to a small change in a complex over-all system. The venture worth W thus represents a single figure which, it is felt, provides a simple and correct yardstick for evaluation of investment worth.

Whether some part of an existing process unit should be replaced is still essentially a problem of maximizing V or W in Equations (7) or (8) respectively. However, for computational purposes some simplifications are possible. Thus total sales realization S will not change often. Also the annual maintenance charges on a plant can be considered usually as a fixed per cent of investment in facilities, and taxes on a portion of the plant will be at the same rate as for the entire plant. Working capital I_w and salvage S_a will often be unaffected by changes like the above. Then the following expressions can be substituted into Equation (7), where C refers to running operating expenses:

$$R = S - C - mI \tag{9}$$

and Equation (11) is obtained.

$$U = C + \left[m + \frac{i(1+i)^n}{(1+i)^n - 1} - dt \right] I \tag{11}$$

Minimizing U will be equivalent to maximizing V since U and V are the only variables in Equation (10). The item in brackets in Equation (11) may be considered as a fixed charge on investment in facilities.

For cases where the return varies from year to year it is necessary to sum a nonuniform series. In this situation expressions (12) and (13) are substituted into Equation (8).

$$R_k = S - C_k - mI \tag{12}$$

Equation (14) is then obtained.

If one desires to study the effect of changing some variable A, entering into the design of a plant, then the desired value of the variable will correspond to

$$\frac{dU}{dA} = 0 \text{ or } \frac{dY}{dA} = 0$$

Thus after differentiation of Equation (11), if one considers C and I to be the only dependent variables, Equation (15) is obtained.

$$-\frac{dC}{dA} = \left[m + \frac{\dfrac{i(1+i)^n}{(1+i)^n - 1} - dt}{1-t} \right] \frac{dI}{dA} \tag{15}$$

A similar expression can be obtained from Equation (14).

Various obvious simplifications can be made in these formulas for special cases, some of which are illustrated in the section "Useful Additions to the Method" on the previous page.

$$V = R - \frac{iI}{(1+i)^n - 1} - (R - dI)t - iI - iI_w + \frac{iSa(1-t)}{(1+i)^n - 1} \tag{6}$$

Venture Profit = Annual Gross Income − Payment to Sinking Fund − Tax − Minimum Acceptable Return − Cost of Working Capital + Annual Credit for Salvage

$$V = (1-t)R - \left[\frac{i(1+i)^n}{(1+i)^n - 1} - dt \right] I - iI_w + \frac{iSa(1-t)}{(1+i)^n - 1} \tag{7}$$

Venture Profit = Annual Gross Untaxed Income − [Interest and Amortization Factor − Tax Credit Factor] Initial Investment − Cost of Working Capital + Annual Credit for Salvage

$$W = \sum_{k=1}^{k=n} \frac{(1-t)}{(1+i)^k} R_k + \sum_{k=1}^{k=r} \frac{d_k t}{(1+i)^k} I - I - \left[\frac{(1+i)^n - 1}{(1+i)^n} \right] I_w + \frac{(1-t)}{(1+i)^n} Sa \tag{8}$$

Present Worth of Venture Profit = Summation of Discounted Gross Untaxed Income + Summation of Discounted Tax Credit − Initial Investment − Present Worth of Working Capital Cost + Present Worth of Salvage Value

$$V = (S-U)(1-t) - iI_w + \frac{iS_a(1-t)}{(1+i)^n - 1} \tag{10}$$

$$W = \left[(S-Y)(1-t) - iI_w + \frac{iS_a(1-t)}{(1+i)^n - 1} \right] \frac{(1+i)^n - 1}{i(1+i)^n} \tag{13}$$

$$Y = \frac{i(1+i)^n}{(1+i)^n - 1} \sum_{k=1}^{k=n} \frac{C_k}{(1+i)^k} + \left\{ m + \frac{\dfrac{i(1+i)^n}{(1+i)^n - 1} \left[1 - \sum_{k=1}^{k=r} \dfrac{d_k t}{(1+i)^k} \right]}{1-t} \right\} I \tag{14}$$

success, the venture worth for complete failure will be as follows:

$$W = (S_a - I)(1 - t) \qquad (19)$$

Much the same thing can be done when the exact life of an equipment item is doubtful. Venture worths can be computed for different years of life expectancy and multiplied by probability factors.

When the effect of more than one variable is involved it would be necessary to express items like C and I in Equation (11) in terms of the variables $A, B, C \ldots$ instead of merely in terms of variable A as was done for the purpose of deriving Equation (15). Sometimes this can be accomplished explicitly. Then differentiation of U with respect to each of the variables and setting $\partial U/\partial A, \partial U/\partial B, \partial U/\partial C \ldots$ equal to zero respectively will result in a series of simultaneous equations which, subject to some limitations, may be solved for the optimum values of $A, B, C \ldots$. The necessary conditions for an optimum at the point where first derivatives become zero include restrictions on the second derivatives (thus for one variable A, d^2V/dA^2 must be negative), continuity of the function involved throughout the range of the independent variables, and absence of optimum conditions at limiting values of one or more of the variables. Often the relationships between the independent variables will be discontinuous or not readily expressible analytically in which case the use of graphs or plots is necessary. Optimums are arrived at by trial and error with all but one variable being held constant at a time and with a series of comparisons. For complex situations where it is possible, however, to express profitability and the various variables involved in determining it as a number of linear relationships, linear programming may be employed (*12*). In general the methods employed in linear programming are trial and error where the trials are determined by mathematical treatment.

Practical Problems in Application

The principles developed above can be applied in three ways: first the selection of alternative complete projects or process plants, second the optimum design of component parts of plants, and third the operation of existing plants.

Distinguishing between projects involving equipment already installed and projects concerned with entirely new investment is important. It is obvious that for equipment already installed many overhead expenses such as depreciation and insurance will occur whether the plant is operated or not. The equipment necessary to supply utilities to a unit which is part of a larger plant is often depreciated over a longer period of time than the process equipment. For detailed analysis of the profitability of a process at a specified plant, it would be necessary to consider to what extent additional investment in such facilities might be necessary. For preliminary studies it is often assumed that utilities may be priced at a unit cost which includes fixed charges (including a minimum acceptable return) on the utility investment.

In the practical design of a plant for a given capacity and product it is customary to employ rules-of-thumb in order to arrive at a preliminary design without spending an excessive amount of time. Theoretically the component parts should all be designed so that the final plant shows the maximum "venture worth." How closely this ideal is approached depends on the relative value of making more exact economic balances as compared with getting the plant into operation sooner.

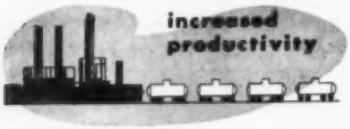
What constitutes a minimum acceptable return rate is a matter for debate. An appropriate rate to assign might well be the average earnings of all companies in the same field of business on total invested capital. If a company could obtain projects, equal or better than this figure, it would certainly be able to meet competition. For the purpose of obtaining an indication of profits in the chemical process industries, compilations such as the annual Facts and Figures résumé are useful (*1*). For 1953, according to this survey, the average for 100 process industries was 11.6% on total invested capital, including working capital.

The same compilation gives information for taking into account working capital. During 1953 average working capital I_w for 100 process industries was 30.6% of original investment in plant and equipment I. It is important to note that incremental additions to capital investment will not usually involve proportional increases in working capital.

In the case of a plant already operating, investment and physical equipment are fixed and it is only necessary to study the effect of throughput on the economics of the operation. Lewis (*8*) and Rautenstrauch (*10*) have presented mathematical formulations for considering the effect of production rate on the economics of individual plant operation and for entire industrial organizations respectively.

The following examples of practical problems illustrate some of the principles developed and discussed above:

PRACTICAL PROBLEMS



Example 1—Illustration of application of basic formulas developed, noting distinction between total incremental return and rate of return.

A. Consider the following project. Management has decided to increase production in a plant unit and has asked its engineering department to survey possible alternatives. The following information has been developed. There are three choices (a) additional facilities to the present equipment at an investment of $200,000 which would return a gross annual profit of $250,000, (b) a new process which involves to some extent use of existing facilities at a new investment of $600,000 with a gross return of $550,000/yr., and (c) a complete new plant costing $1,000,000 which would return a gross profit of $700,000/yr.

The following assumptions are made. The minimum attractive return rate i on invested capital after taxes and depreciation is 15%. State and Federal income taxes will total 50%. There will be no salvage value S_a of any of the equipment and none of the alternatives involve any variation in working capital I_w, which will be taken constant at $100,000. The government will allow the equipment to be written off in five years, but it is anticipated that the plant life will be ten years. For simplicity straight-line depreciation will be employed for tax write-off (though other methods could be employed as shown in Example (*2*)).

Solution: formula (8) will be employed. $R \& d = 1/5 = 0.20$ are constants.

$$\sum_{k=1}^{k=n} \frac{1}{(1+i)^k} = \frac{(1+i)^n - 1}{i(1+i)^n}$$

Case (a),

$$W = 250{,}000(0.5)\left[\frac{(1+0.15)^{10}-1}{0.15(1+0.15)^{10}}\right]$$

$$+ 200{,}000(0.2)(0.5)\left[\frac{(1+0.15)^{5}-1}{0.15(1+0.15)^{5}}\right]$$

$$- 200{,}000 - \left[\frac{(1+0.15)^{10}-1}{(1+0.15)^{10}}\right]100{,}000$$

$$\frac{(1+0.15)^{10}-1}{0.15(1+0.15)^{10}} = \frac{4.05-1}{0.15(4.05)} = 5.02;$$

$$\frac{(1+0.15)^{5}-1}{0.15(1+0.15)^{5}} = \frac{2.01-1}{0.15(2.01)} = 3.36$$

$$W = 626{,}000 + 134{,}500 - 200{,}000 - 75{,}300 = \$485{,}200$$

Case (b),

$$W = 550{,}000(0.5)(5.02) + 600{,}000(0.2)(0.5)(3.36) - 600{,}000 - 75{,}300 = \$906{,}700$$

Case (c),

$$W = 700{,}000(0.5)(5.02) + 1{,}000{,}000(0.2)(0.5)(3.36) - 1{,}000{,}000 - 75{,}300 = \$1{,}020{,}700$$

For the problem as stated, Case (*c*) is the most attractive of the three mutually exclusive alternatives.

B. Suppose now it is assumed that if money is invested in either of the above three alternates it will take two years to get into successful operation and that the process will become obsolete after eight more years of successful operation.

Solution: we will still employ formula (8). However, in this case $R_k = 0$ for $k = 1$ and 2 and,

$$\sum_{k=3}^{k=10} \frac{1}{(1+i)^k} = \frac{(1+i)^{10-2} - 1}{i(1+i)^{10}} = \frac{(1.15)^8 - 1}{0.15(1.15)^{10}} = 3.38$$

for $i = 0.15$. All terms in formula (8) except the first are unchanged and therefore the following result is obtained:

Case (a),

$$W = 250{,}000(0.5)(3.38) + 134{,}500 - 200{,}000 - 75{,}300 = \$281{,}200$$

Case (b),

$$W = 550{,}000(0.5)(3.38) + 202{,}000 - 600{,}000 - 75{,}300 = \$456{,}700$$

Case (c),

$$W = 700{,}000(0.5)(3.38) + 336{,}000 - 1{,}000{,}000 - 75{,}300 = \$443{,}700$$

For this variation note that Case (*b*) shows up the best.

C. Suppose now with the premises of A except that instead of the above three alternatives being mutually exclusive, all three present possible investment opportunities. If unlimited funds are available, we would invest in all three propositions, assuming a minimum acceptable return rate of 15% on invested capital. However, if maximum available funds were limited to some figure betwen \$1,100,000 and \$1,800,000, it is clear that we would have the alternative of investing in (*a*) + (*b*) equivalent to $W = \$1{,}391{,}900$ or (*c*) alone equivalent to $W = \$1{,}020{,}700$. Since (*a*) + (*b*) gives a larger value of total W, it is the correct alternative.

Another way of judging relative attractiveness would be to compute v by formula (16) selecting projects in order of decreasing value of v until the limiting value of $I + I_w$ is reached.

(see above)

Case (a),

$$v = \frac{485{,}200}{300{,}000} \times \frac{1}{5.02} = 0.323$$

Case (b),

$$v = \frac{906{,}700}{700{,}000} \times \frac{1}{5.02} = 0.257$$

Case (c),

$$v = \frac{1{,}020{,}700}{1{,}100{,}000} \times \frac{1}{5.02} = 0.185$$

(*a*) is first chosen since it gives highest v, then (*b*); (*c*) is eliminated because choosing it will result in exceeding allowable $I + I_w$. This method may give an erroneous result if the final combination selected falls far short of the maximum allowable $I + I_w$. Thus suppose the maximum $I + I_w$ were \$1,100,000 and $I + I_w$ for *Case* (*b*) were \$350,000, with $v = 0.257$ as above. Then the selection of (*a*) + (*b*) would yield $W = \$938{,}550$ vs. $W = \$1{,}020{,}700$ for Case (*c*), which latter would now be the correct choice on the basis of maximum total venture worth.

Example 2—Calculation of best method of depreciation of investment for tax purposes.

In view of the fact that the 1954 income tax law allows three alternative methods for depreciation for tax purposes, it is desired to analyze which method of deduction is most attractive. It is clear from formula (8) that the only way depreciation for tax purposes enters into the picture is in the term

$$\sum_{k=1}^{k=n} \frac{d_k}{(1+i)^k} tI$$

which represents the present worth of the tax credit. It is proposed to analyze the situation for values of minimum acceptable return $i = 0.05$ and 0.10, for allowable life $r = 5$ and 10 years.

As an alternative to straight-line depreciation, the most widely used method under income tax law up until 1954, the following methods may now be employed for income tax purposes:

A. double declining balance method
B. sum-of-the-digits method
C. any other consistent depreciation method which would not give an aggregate depreciation write-off at the end of the first two thirds of the useful life any longer than by method (A).

Also at any time it is allowable to switch from the double declining balance method to straight-line depreciation with respect to the undepreciated balances. This is in order to take care of the failure of the double declining balance method to depreciate fully an asset at the end of its life. The taxpayer, using the sum-of-the-digits method, cannot change to straight-line depreciation, as is permitted under the declining balance method.

The declining balance rate is determined by first computing the straight line rate = $100\%/r$, where r is the life (for tax purposes). Under the double declining balance method, twice the rate so determined is applied to each year's remaining unrecovered cost. Thus if the useful life is five years, the straight-line rate is 20% and the first year's double declining balance rate will be 40%. If the original investment value is I, depreciation the first year is 0.4 I, the second year it is 0.24 I (unrecovered cost of 0.6 $I \times 40\%$), etc.

The sum-of-digits method employs a fraction, the numerator of which is the remaining life of the facility at the beginning of the tax year, and the denominator is the sum of the individual digits corresponding to years of useful life at acquisition. Thus with a life of five years, the sum of the digits will be $1 + 2 + 3 + 4 + 5 = 15$, the depreciation for the first year will be $5/15 = 33.3\%$. If the value of the facility is I, depreciation for the first year is 5/15 I; depreciation for the second year is 4/15 I, etc.

By elementary methods (*4*) the following formulas may be developed showing the annual depreciation and the present worth of the tax credit for the three methods currently proposed.

In the case of the combination of the double declining balance and the straight-line method the present worth of the

tax credit can be expressed by the formula

$$\sum_{k=1}^{k=r}\frac{dk}{(1+i)^r}=\left(\frac{2}{r}\right)\frac{1-\left(\frac{r-2}{r(1+i)}\right)^{s-1}}{\frac{r+2}{r}}+\frac{\left(\frac{r-2}{r}\right)^{s-1}}{r-s+1}$$

where s is the year of operation in which the switch from one method to the other is made.

Table 2 constructed by applying the above formulas shows how the three methods and the optimum combination of double declining balance and straight-line depreciation compare for the return rates and allowable life periods noted. In the case of the combination method the switch from double declining balance to straight line is made at the point which gives the maximum deduction (e.g., 4th year for a 5-year life, 6th year for a 10-year life).

The best choice lies between the combination method and the sum-of-the-digits method, the former being favored at low values of r.

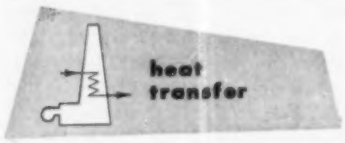
Table 1.—Formulas for Tax Credits

Method	Annual Deduction d_k	Present Worth Summation $\sum_{k=1}^{k=r}\frac{d_k}{(1+i)^k}$
Straight line	$\frac{1}{r}$	$\frac{1}{r}\left[\frac{(1+i)^r-1}{i(1+i)^r}\right]$
Double declining balance	$\left(1-\frac{2}{r}\right)^{k-1}\left(\frac{2}{r}\right)$	$\frac{1-\left[\frac{r-2}{r(1+i)}\right]^r}{1+\frac{1}{2}ri}$
Sum-of-the-digits	$\frac{2(r-k+1)}{r(r+1)}$	$\frac{2}{r(r+1)i}\left[r-\frac{(1+i)^r-1}{i(1+i)^r}\right]$

Table 2.—Comparison of Tax Credit as a Fraction of Investment

(summation of present worth credits for individual years)

Method	Life 5 years; $r=5$		Life 10 years; $r=10$	
	$i=0.05$	$i=0.10$	$i=0.05$	$i=0.10$
Straight Line	0.866	0.758	0.772	0.615
Double declining balance	0.834	0.761	0.747	0.638
Sum-of-the-digits	0.894	0.805	0.827	0.701
Combination	0.898	0.812	0.818	0.685



Example 3—Economic approach temperature in heat exchange.

Typical of problems of optimum design.

It is desired to determine the optimum-temperature approach between flue gases from a furnace and a waste heat boiler recovering heat from these gases.

Assume that sufficient draft is available so that no blower or stack is required, that equipment will operate 8,400 hr./cal. yr., and that steam will be generated at 100 lb./sq.in. gauge. Incremental waste heat boiler surface dI/dA is taken at \$3.00/sq.ft. installed and an over-all coefficient of 5 B.t.u./(hr.)(sq. ft.)(° F.) is obtainable. The estimated value of steam is \$0.48/1,000 lb. The heat required to produce 1 lb. of steam at 100 lb./sq.in. gauge from water at 90° F. is 1,133 B.t.u.

The equipment is to be installed in a chemical plant which has an estimated life of ten years. The minimum acceptable return after taxes and depreciation may be taken at 10.0% on initial investment. Federal plus State income tax is taken at 50%/yr., and it is assumed that the sum-of-the-digits method described in Example 2 will be employed. Incremental maintenance and other fixed charges will amount to 6%/yr. on investment. Working capital will not be affected by equipment size.

Solution: formula (14) will be applicable and it will be noted that C_k will be a constant so that the summation indicated in the first term on the right-hand side of Equation (14) will reduce to C. Thus the following applies:

$$-\frac{dC}{dA}=\left[m+\frac{\frac{i(1+i)^n}{(i+i)^n-1}\left(1-\sum_{k=1}^{k=10}\frac{d_kt}{(1+i)^k}\right)}{1-t}\right]\frac{dI}{dA}$$

The reduction in steam requirement effected by the last square foot of waste heat boiler surface installed must equal an annual charge at a rate equal to the items in brackets. The value of this is as follows, from appropriate items in Table 2:

$$0.06+\frac{\frac{1}{6.15}\left[1-0.701\times0.5\right]}{0.5}=0.272$$

Therefore, from the above equation:

$$-\frac{dC}{dA}=(0.272)(3.00)$$

$$=0.816\ \$/(\text{yr.})(\text{sq.ft.})$$

Since heat transferred per hour per square foot,

$$q/\theta=5\times1\times\Delta t,$$

the savings made per calendar year on the last square foot will be

$$-\frac{dC}{dA}=\frac{(5\times1\times\Delta t)(8400)(0.48)}{(1000)(1133)}$$

$$=0.0178(\Delta t)\$/(\text{yr.})(\text{sq.ft.})$$

Equating the values of $-dC/dA$ above gives the required Δt as follows:

$$0.816=0.0178\ \Delta t$$

$$\Delta t=45.8°\text{ F.}$$

Note that it is only when one of the media is at constant temperature or for parallel flow heat exchange that incremental area exchanges heat at the outlet temperature difference. Often problems of this type are more complicated, involving costs for fluid pumping and countercurrent flow of fluids which change in temperature. Such references as Perry's Handbook (*9*) consider these cases but do not give details for the methods which should be used for including minimum acceptable return and tax in the economic balance.

Several examples similar to the above are worked out by Smith and Dresser (*11*) in an article accompanying this one. Their treatment may be supplemented by this article as regards a method for calculating *stipulated incremental payout*, equivalent in the above nomenclature to:

$$\frac{\frac{i(1+i)^n}{(1+i)^{n-1}}\left(1-\sum_{k=1}^{k=r}\frac{d_kt}{1+i)^k}\right)}{1-t}$$

Example 4—Replacement vs. maintenance in existing plants

Discussion of alternative methods.

The following example after Jelen (7) illustrates alternative methods for solving replacement problems. A piece of equipment in a highly corrosive atmosphere lasts five years and costs \$10,000. How much can be spent per year on painting if the life is extended ten years. Assume $t = 0.5$ and $d = 1/n$, *i.e.*, depreciation for tax purposes is straight line. Minimum acceptable return rate after taxes is 10.0% and maintenance $m = 0$.

Solution: formula (11) will be employed. The value of U without painting corresponds to a life of five years, and is as follows:

$$U_1 = \left[\frac{\frac{0.10(1+0.10)^5}{(1+0.10)^5-1} - \frac{0.50}{5}}{1-0.50}\right]$$

$$10{,}000 = \$3{,}280$$

For the case with painting and a life of ten years, if X is the unknown annual payment for painting, the following applies:

$$U_2 = X + \left[\frac{\frac{0.10(1+0.10)^{10}}{(1+0.10)^{10}-1} - \frac{0.50}{10}}{1-0.50}\right]$$

$$10{,}000 = X + 2{,}260$$

By equating the $U_1 = U_2$ we obtain:

$$3{,}280 = X + 2{,}260; \quad \therefore X = \$1{,}020$$

We can spend \$1,020/yr. for painting over a ten-year period to extend the life from five to ten years.

For cases like the above where services for equal periods of time (10 years) are being compared, it can be shown by means of the approximation for the interest and amortization factor (Equation (18)), that the answer can be obtained rather closely without assuming values for either i or t. Thus, if Equation (18) is applied, Equation (11) with $m = 0$ becomes,

$$U = C + \left(\frac{1}{n} + \frac{0.65i}{1-t}\right) I$$

In the above example, the following values for $U_1 + U_2$ then result:

$$U_1 = \left(\frac{1}{5} + \frac{0.65i}{1-t}\right) I;$$

$$U_2 = X + \left(\frac{1}{10} + \frac{0.65i}{1-t}\right) I$$

Therefore, setting $U_1 = U_2$ results in $X = 1/10\ I = \$1{,}000$ which checks the above.

Jelen (7), making such comparisons, has employed capitalized cost, not making any allowance for taxes. His solution for the above problem for $i = 0.04$ and $t = 0$ is \$974 as the annual expenditure, which again checks the above.

Acknowledgment

The author wishes to thank Wayne A. Howard of Socony Mobil Oil Co. for helpful suggestions regarding literature references, and Howard Brenner, of N. Y. University, for assistance in review and in the derivation presented in the Appendix.

Appendix

It is desired to determine the best value for the constant k in the following approximation formula for capital recovery factor:

$$\frac{i(1+i)^n}{(1+i)^n-1} = \frac{1}{n} + ki \qquad (1)$$

In order to minimize the sums of squares of errors, the following equation must be satisfied:

$$\frac{d}{dk}\int_{n_1}^{n_2}\int_{i_1}^{i_2}\left[\frac{i(1+i)^n}{(1+i)^n-1} - \frac{1}{n} - ki\right]^2 dn\,di = 0 \qquad (2)$$

In the present case, we wish to obtain the best value for k when $n = 5$ to 20 and $i = 0.05$-0.15.

Since the limits of integration do not depend on k, we can perform the differentiation under the integral sign and thus:

$$\int_{n_1}^{n_2}\int_{i_1}^{i_2} i\left[\frac{i(1+i)^n}{(1+i)^n-1} - \frac{1}{n} - ki\right] dn\,di = 0 \qquad (3)$$

After some reduction this expression becomes the following:

$$\int_{n_1}^{n_2}\int_{i_1}^{i_2}\frac{i^2}{(1+i)^n-1}\,dn\,di - 0.01\ln 4 + (1-k)0.01625 = 0 \qquad (4)$$

The double integral in Equation (4) can be integrated with respect to n and the remaining single integral is evaluated numerically using Simpson's rule.

Finally we obtain $k = 0.6524$. (The author has copies of the complete derivation available for the asking.)

Notation

- A = an independent design variable (e.g., heat-transfer area)
- C = running operating expenses, \$/yr.
- I = capital invested in equipment, \$ (either entire plant or some portion under consideration)
- I_w = working capital, \$
- R = gross profit (before depreciation and taxes), \$/yr.
- S = total sales realization, \$/yr.
- S_v = salvage value, \$
- U = a function related to V by Equation (10), \$/yr.
- V = venture profit, net profit less il, defined by Equation (6), \$/yr.
- W = venture worth, present worth of venture profit, defined by Equation (8), \$
- Y = a function related to W by Equation (13), \$/yr.
- d = depreciation rate for tax purposes, fraction/yr.
- i = minimum acceptable rate of return on investment, fraction/yr.
- k = a constant; subscript denoting a year of operation
- m = charges directly attributable to investment such as maintenance, fraction/yr.
- n = project life, yr.
- r = period allowed for tax write-off, yr.
- s = year of operation in which switch is made from double declining balance to straight-line method
- t = income tax rate, Federal plus State, fraction
- v = rate of return corresponding to V or W, defined in Equation (16), fraction/yr.

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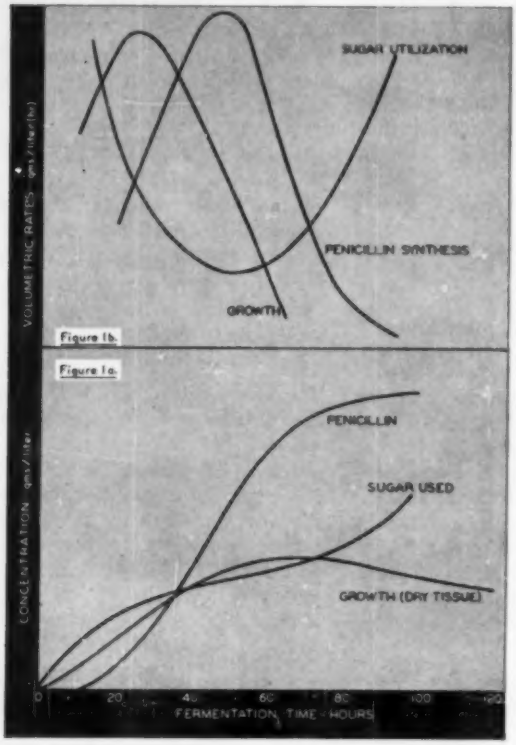

fermentation

—A CHEMICAL ENGINEERING APPROACH

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The great resurgence, after 1945, of fermentation as a chemical production technique has been characterized by several marked changes in types of processes and equipment employed. Perhaps the most notable of these is in the nature of products manufactured. Before World War II, fermentation was mainly employed for the production of bulk organics, solvents in particular, of relatively simple molecular structure, and low unit cost. Now the very opposite is true. Biosynthesis of complex molecules of high unit cost (note B-12) is the order of the day. Incidentally, only citric acid has maintained its place as a major fermentation product in both these eras, which suggests that structural complexity may be a more important factor than price in determining the feasibility of biosynthesis methods.

Other important differences are also worth noting. For one thing, all the major pre-1940 products (except citric acid) were prepared by anaerobic or similar processes requiring little or no forced aeration, whereas present processes all require rather substantial aeration. Furthermore, though cleanliness was certainly important, these earlier processes were little affected by slight contamination, and operations were generally only semisterile. Now, on the other hand, the maintenance of a high order of sterility is absolutely imperative and contamination prevention is a major concern.

In addition to these technical differences between current fermentation processes and their antecedents, there has been an even more drastic, though less apparent, change in approach. It was formerly held that fermentation is a special type of chemical process, involving natural phenomena the optimum conditions of which may be established by careful observation and then should not be tampered with. Now it is generally recognized that fermentations, although highly complex, are identical in principle with the more familiar chemical processes which we have long studied and reasonably mastered. If this premise is granted, it follows that fermentations should respond in a predictable manner to changes in process variables. (This statement will undoubtedly be a little too strong for many of the more traditionally minded members of the industry but it is really not very startling.) The real difficulty, of course, is not that there is something special about fermentation but rather that these processes are so complex in detail that it is extremely difficult to isolate clear cause-and-effect relationships.

This changing attitude toward fermentation and its growing acceptance as a regular chemical manufacturing technique has been closely tied to the increasing role of chemical engineers in the field. Engineers are now as much concerned with the whole process as with its mechanical problems. In short the chemical engineer is assuming his full and proper responsibility in fermentation technology. The rest of this paper will attempt to clarify the nature of this responsibility by offering a chemical engineering interpretation of fermentation.

Despite any specific biochemical connotations, the term "fermentation" is used now to denote any microbiological method for chemical production. Actually a more complete statement of the essential nature of industrial fermentation processes would be: chemical manufacture by means of enzyme catalyzed reactions with microorganisms as the source of the enzyme-catalysts. Even this definition is not a firm one, for one certainly is not limited to microorganisms as a catalyst source. Many other types of tissue, like animal glands and plant homogenates, have already been employed experimentally.

Viewed in this light, the one basic difference between biosynthesis and the more common chemical production methods becomes apparent. In principle they are identical; in practice it is the complex and variable nature of the biochemical catalysts, enzymes, which sets them apart.

Catalysis and Enzymes

In the oxidation of SO_2 to SO_3 for sulfuric acid manufacture catalysis is required and either vanadium pentoxide (V_2O_5) or some type of active platinum like platinized asbestos is commonly employed. There is, of course, some actual loss of catalyst material through attrition as well as a gradual decrease in specific activity due to accumulated fouling and poisoning so the bed must be regenerated or renewed periodically. Although a microbiological conversion may be just as clear cut chemically, the problem of preparing and maintaining the proper catalyst in its most active form is infinitely more complex. One must depend on the growth processes of living cells to produce the needed catalytic agents and hence have, at best, only an indirect control.

For instance, the oxidation of glucose to gluconic acid by the mold *Aspergillus niger* is about the only industrial fermentation process in which the specific reaction system is reasonably well elucidated. In fact the transformation can be effected by a cell-free enzyme preparation which has been rather exhaustively studied. The specific catalytic agent (enzyme) is called glucose aerodehydrogenase in conformity with the accepted parlance of enzymology. It is formed by the mold in sufficient concentration for economical conversion only under certain conditions of growth and it is necessary to provide these conditions in the fermentation medium employed. Furthermore this enzyme-catalyst requires certain promoters, called "cofactors" by the enzymologists, in order to operate efficiently. These are normally supplied shotgun style by inclusion in the medium of various complex natural supplements or through the addition of small amounts (traces) of various cations.

In essence then, the fermentation problem is that of carrying on a catalytic reaction in which the catalyst (more likely catalysts) concentration and activity may change at substantial rates. Furthermore these changes are only indirectly controllable since the catalyst is added to the system by living cells already present, and withdrawn or altered through a variety of complex processes little known or understood. With this basic picture of fermentation in mind, one can understand now how each of the chemical process fundamentals outlined earlier applies. Obviously even the most elementary analysis of this type will be difficult because of the intricacies of the systems studied. Nevertheless it must be remembered that the inability to identify and isolate the relationships one wants to deal with in any case does not mean that they do not exist.

Three characteristic commercial fermentation processes have been selected to illustrate the following discussion. In Table 1 these processes are summarized in two ways: first the data normally given in the fermentation literature are presented; second this information is broken down into terms more normal to chemical engineering. It is immediately evident that from the chemical engineering–or physical chemical–viewpoint much pertinent information is simply unknown. This is, of course, the real stumbling block in fermentation process design.

Stoichiometry

Perhaps the first consideration in chemical process design is the establishment of mass relations between reactants and expected products. While rarely a problem in ordinary chemical synthesis—at least with respect to the major product—stoichiometry is seldom as simple a matter in fermentations. In some processes like the oxidation of glucose to gluconic acid, and compound S to cortisone and hydrocortisone (Table 1), or the conversion of glucose to ethanol and CO_2, the necessary stoichiometric relationships are reasonably well established. In other cases like penicillin (Table 1), streptomycin, or vitamin B-12 biosynthesis they are known only partially or not at all.

If the stoichiometry for the process is unknown, it is not possible to express reaction efficiencies in terms of yields or % conversion. Instead a special nomenclature has developed using productivity, or mass of product formed per unit volume per hour of reaction time, as the basic standard of comparison. Of course material balances may still be written for these cases, but as they cannot tie products to reactants, they can be little more than bases for cost accounting.

It may be wise to add here one word of caution. Although it is recognized that the stoichiometric relationship for a reaction does not necessarily indicate the actual mechanism, this point cannot be overemphasized with respect to biochemical reaction systems. The thoroughly studied alcoholic fermentation, represented by the expression

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2,$$

involves a long and complex series of enzymatic reactions of which the simple equation just shown takes no account.

Energy Relationships

The interpretation of energy relationships in microbiological processes also presents problems. When an energy input is required in order to cause a particular reaction to proceed ($\Delta F = +$), the usual recourse is to heat as the energy source. Microorganisms and their enzymes are so temperature-sensitive, however, that this approach cannot normally be employed to any degree. Instead the free energy input required for synthesis of complex molecules in fermentation is obtained by coupling the synthetic processes ($\Delta F = +$) to various energy-yielding reactions ($\Delta F = -$). Carbohydrate (sugar) oxidation is the most common of these, but the hydrolysis and oxidation of proteins and fats may also be important.

Kinetics and Equilibrium

No aspect of fermentation technology is as lacking in basic knowledge and experimental data as the matter of kinetics. Rates of formation of desired products and their relation to process variables have only recently received any consideration at all in the literature (*3, 4*).

One matter which has never bothered the fermentation process designer is the question of chemical equilibrium. Not only do these processes involve a long series of stepwise reactions, often essentially irreversible, but the absolute quantities and concentrations of reactants and products are so low that the mass-action principle has never been considered. Whereas this is probably all right, it is nevertheless worth noting that the steady increase in product concentration being brought about through empirical experiment is pushing

these values to substantial levels. If mass action does not, then at least solubility limits may present a problem before long.

Plant fermentations generally are carried out batchwise under conditions which have been selected to give the maximum productivity–mass of product/volume (time). Typical fermentation data for the penicillin process of Table 1 are shown in Figure 1*a*. In this case the organism was germinated from spores in one or more "inoculum" or seed stages and there is consequently little delay or lag in the initiation of growth and sugar utilization. On the other hand, there is a significant one for penicillin production.

From these data it is possible to obtain at least a partial picture of the several important rate processes during the fermentation cycle. This pattern is presented in Figure 1*b* (*4*). Sugar-utilization values are an approximate measure of the rate at which free energy is being drawn from energy-yielding sources, and tissue synthesis is an even cruder indication of the rate at which catalyst is being added to the system. The key rate pattern, penicillin synthesis, depends at any point on the concentration of the unknown reactants, catalysts, and their required cofactors, and, of course, on the other properties of the system like temperature, *p*H, etc.

It is obvious from Figure 1 that growth (catalyst formation) is maximized at a different time, and hence under different conditions, from penicillin biosynthesis. Yet the very nature of the batch-fermentation technique imposes conditions on both these processes which, if not identical, are very similar. In reality then, the empirical selection of fermentation conditions which we now use amounts to arranging that compromise between optimum conditions for energy transfer, catalyst synthesis, and product formation which gives maximum productivity. Although this has certainly been necessary in the past, it is not reasonable. One would hardly attempt to carry out the oxidation of SO_2 previously noted under the same conditions which are used to prepare the V_2O_5 catalyst.

One obvious alternative would be to change conditions from time to time during the batch run. There is nothing basically wrong with this proposal; the problem is that it is difficult to carry out in practice. Constant vigilance against chance contamination, plus the accessory requirement that the whole unit and its contents must be sterilized at the start, makes such simple operations as the addition of reagents and *p*H adjustment extremely difficult. Even more important, however, is the previously mentioned special attitude toward fermentation which has caused the most obvious techniques of process control to be ignored. In any event there is a far better solution to the problem than this.

Table 1.—Summary of Typical Industrial Fermentation Processes

FERMENTATION DATA			
Product	Gluconic acid (*1*)	Hydrocortisone (*5*)	Penicillin (*2*)
Organism	*Aspergillus niger*, NRRL 3	*Cunninghamella blakesleena*	*Penicillium chrysogenum*
Medium (start)	g./l. Glucose ..... 240.0 CSL ..... 2.0 $(NH_4)_2HPO_4$ ..... 0.4 $MgSO_4 \cdot 7H_2O$ ..... 0.2 KH_2PO_4 ..... 0.2 Urea 0.1	g./l. Glucose ..... 20 Soybean meal ..... 5 Peptone ..... 5 NaCl ..... 5 KH_2PO_4 ..... 5 Yeast extract 3	g./l. Lactose ..... 25 Glucose ..... 10 CSL ..... 40 $NH_4 \cdot$ acetate ..... 1.5 Na_2SO_4 ..... 1.0 $CaCO_3$ 10
(added)	NaOH—to keep pH at 6.0-6.5	Compound S—at 18 to 48 hr.	Phenylacetic acid—0.5 g./l. every 12 hr.
Temperature	30° C.	24° C.	27° C.
Fermentation time	20 to 25 hr.	36 to 72 hr.	120 hr.
Conversion (or final concentration)	90-95%	15% (probably much higher, about 50% in practice)	1600 units/ml. or 1 g./l.
Reactant	Glucose	11-desoxy-17-hydroxycorticosterone (compound S)	phenylacetic acid + ?
PROCESS DESIGN DATA			
Product	Gluconic acid	17-hydroxycorticosterone (compound F) (hydrocortisone)	benzypenicillin (G)
Catalyst	Glucose aerodehydrogenase	?	?
Promoters	Mg^{++}	?	?
Raw material for catalyst synthesis	$(NH_4)_2HPO_4$, urea, CSL	Soybean meal, yeast extract	CSL, $NH_4 \cdot$ acetate
Energy source	Glucose + $O_2 \rightarrow CO_2 + H_2O$ $\Delta F_{25°C.} = -686$ kcal./mole	Glucose + $O_2 \rightarrow CO_2 + H_2O$	Lactose / Glucose + $O_2 \rightarrow CO_2 + H_2O$
Average rate of synthesis (productivity)	15 g./l.(hr.)	?	0.006 + g./l.(hr.)

CSL = corn steep liquor

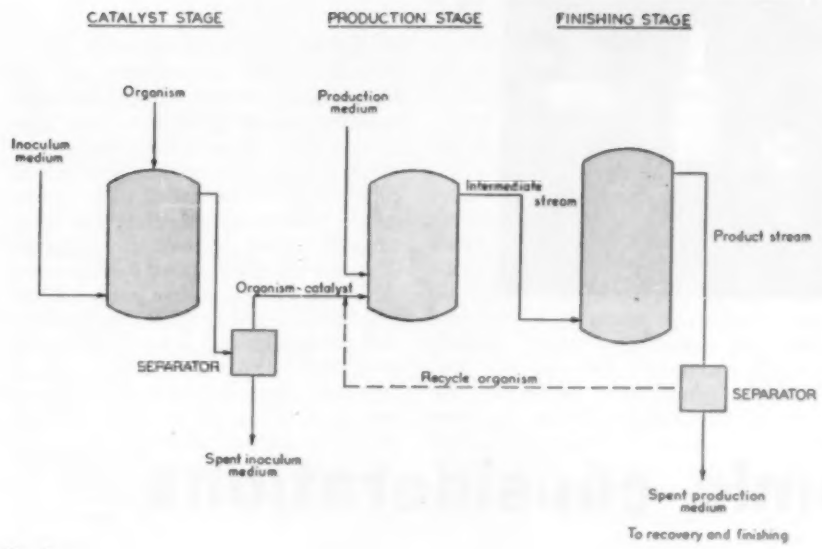

Fig. 2.

The Ideal Fermentation Process

Recognizing that our ideas will undoubtedly change tomorrow, we can nevertheless postulate an ideal fermentation process on the basis of the considerations made so far. This system will, of course, be a continuous one, not only for the advantages normally offered by continuous operation but also because it will permit physical separation of the major phases of the process. The proposed fermentation system is presented schematically in Figure 2.

The most important feature of this type of operation is the physical separation of catalyst and product synthesis activities. Only two continuous, overflow-type reactors are essential, but it probably would be wise to employ a third, or finishing unit as shown to permit more complete utilization of raw materials.

In the initial or catalyst stage active enzyme-catalysts are being produced by growing the appropriate organism. Conditions employed here will be those which give rapid synthesis of tissue possessing a maximum specific activity measured in terms of conversion rates for the reaction being carried out in the production stages. The exit stream from this first stage may be sent to a separation unit where the organism (catalyst) is removed for transfer to the production reactor or the entire effluent from the catalyst stage may simply be pumped over into the production unit. Which of these alternatives should be followed must be determined for each particular case.

If the medium and conditions employed in the production stage are reasonably like those in the catalyst stage about the only effect of adding the entire effluent will be one of dilution. This should lower the rate of conversion by reducing the effective concentration of reactants and catalyst. Separation of the catalyst, on the other hand, increases the dangers of contamination and also requires that the active enzyme-catalysts be associated with the tissue proper. If they have been elaborated into the medium by the organism, the separation step shown will be useless. Actually the ultimate aim should be not just to recover the full enzyme complement of the cells but rather to select the specific ones for the desired conversion. The practical possibility of accomplishing this is, for the moment, rather remote but it must be kept in mind.

In the second, or production stage, the active catalyst is brought together with reactants, promoters, and any other required substances, under conditions that will offer the maximum conversion rate. Retention time in this stage, and hence its volume for any specified plant output, will depend on the conversion rate, degree of conversion desired, and the initial reactant concentration.

Since complete conversion may require an excessive retention time and volume, a third stage can be used. This finishing stage is, of course, only a continuation of the production stage to permit more complete conversion or utilization of raw materials. It is nevertheless quite reasonable to operate it under different conditions if a reduced volume may be so achieved. This two-stage operation is quite analogous to the SO_2 oxidation example cited earlier where two conversion stages are employed. The first, at about 450° C., gives rapid but incomplete conversion of SO_2 to SO_3. The second, at about 375° C., provides for near completion of the oxidation at a lower rate.

It is also possible to recycle all or part of the organism-catalyst from the final stage as shown, but the manipulative problems involved may make this procedure impractical. Actually the reuse of microbiological tissue is not new, the technique of "replacement cultures" having been used in laboratories since the early days of industrial microbiology. Successful recovery and reuse of *A. niger* mycelium for as many as thirteen successive gluconic acid fermentations has been demonstrated (*6*).

Finally, the practicality of a system illustrated in Figure 2 requires consideration. It is easy to describe on paper but what chance has it for commercial application? Actually the main impediment to continuous fermentation practice has been the contamination problem. Continued improvement in equipment and refinement of operating procedures during the last decade has certainly reduced greatly, although not eliminated, this difficulty, and it is reasonable to expect that continuous fermentation may be carried out with an incidence of contamination no higher, and perhaps lower, than batch processes.

An examination of Table 1 also reveals another point of interest. In the microbiological sterol conversions (cortisone, hydrocortisone) there is evident for the first time a process of considerable current economic value, the essential chemistry of which and hence stoichiometry, is known. Furthermore, the close analogy between these processes and gluconic acid production is evident and the great fund of knowledge now on account from gluconic acid studies should provide a good basis for interpreting the newer processes. In short, the application of fundamental chemical-process concepts to this accumulated information and experience may make the sterol processes the first truly "engineered" commercial fermentations.

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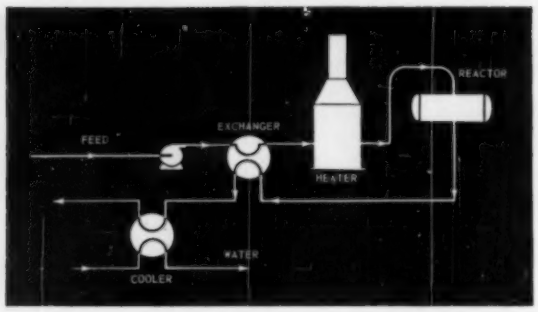

Fig. 4.

some economic considerations

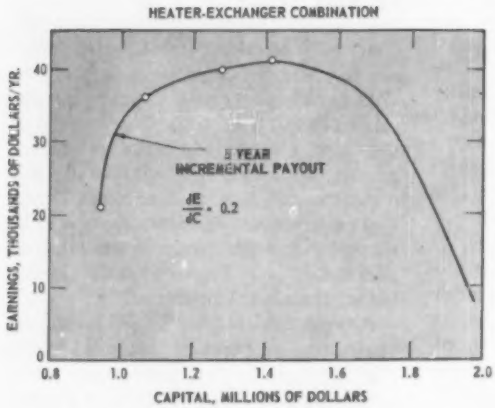

Figure 3. Heater-exchanger combination.

IN PROCESS DESIGN

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A discussion of how best to balance increased investment against the expected additional savings or profit such investment will yield.

We have entered a period in which the cost of equipment is being more closely scrutinized. It is important in the design of complex units that the profitability of the whole unit should not be permitted to obscure deviations from maximum profitability of the various parts. Thus, it is most important that *all* of the money allowable for buying efficiency must be spent. The amount of money allowable for this purpose can be readily and accurately determined.

Capital cost reduction is certainly one of the basic functions of process design. A proper economic balance between capital, running expense, and maintenance, varying in detail, should be considered in all aspects of a design.

These balances fall into two groups: (1) the simple maximum or minimum, and (2) the stipulated incremental payout.

The first group of balances is confined to those cases in which either capital is constant and operating cost varies or capital varies and operating cost is constant. In such problems as choosing tank diameters, selecting tube size for a heater, and the like, the operating cost is constant, but the capital will vary with the diameter. A well-developed minimum cost based on tank diameter, for example, can readily be found as shown in Figure 1. In the other case occur such examples as the point-of-discard of catalyst in a reactor. Figure 2 shows the case for earnings from a catalyst charge during its life. An absolute maximum is obtained. The capital invested in catalyst remains constant during the run. Yield declines with catalyst age, and although the cost of the catalyst per barrel of feed declines with each additional barrel processed, the slowly accelerating yield decline eventually catches up and net earnings decline. At this point the catalyst must be discarded to maintain maximum profit.

The second group of balances depends on the incremental payout desired. When both capital and operating charges vary with equipment sizing, earnings are plotted against capital, and a curve of the type shown in Figure 3 is obtained. This is typical of the situation when one is buying on a criterion of efficiency. In general, more efficiency can be gained by investing more capital, but beyond a certain point, added efficiency is purchased at a decreasing rate per dollar. This is the well-known law of diminishing returns. One soon reaches a point of maximum earnings, and this is where a great deal of confusion has occurred. In contrast to the first group of balances, where an absolute maximum of earnings or minimum capital was the criterion, in this type of balance the maximum earnings point is not the optimum. The point of stipulated incremental payout is the optimum. At the maximum point on this curve, the last dollar invested brings no return—that is, the incremental earnings are zero. For maximum profit, all the money necessary to reach the stipulated incremental payout should be spent, but no money should be spent beyond this to reach the maximum earnings point.

Thus, the greatest rate of return on money is at zero investment, and the point of greatest gross return gives no return on the last dollar invested. The engineer desires to push in the direction of maximum efficiency, while, on the other hand, the financier has a minimum limit on the returns he would like to get on his money. Companies in a good financial position can afford to expend greater sums on buying on the basis of the efficiency criterion and can, therefore, set a longer period for the stipulated incremental payout. Serious thought must be given to the current value of this criterion, depending on average earnings rate, economic environment, credit rating, and the fields a company may want to enter. Petroleum refineries may use three to five years; petrochemical industries, one to three years; and where an extremely stable process is involved, longer payouts may be desirable.

There is less risk with the individual parts of a unit than there is with the whole unit. Markets change; prices on raw materials change. The evaluation of a project involves considerable risk of this nature. But most of the individual pieces of equipment affecting efficiency, such as exchangers, heaters, and turbines, involve a minimum of risk as regards their performance. As long as the plant operates, a return on the money can be expected from improved efficiencies for these parts. Thus, the earnings of the individual equipment are very largely independent of the earnings of the plant as a whole.

Designing equipment to improve efficiency involves the addition of small increments of equipment and determining the individual economics. This is most easily seen in the case of the heat exchanger. Every time a square foot is added, heat is saved, but as surface is added, the heat saved per square foot decreases. We cannot look at the earnings of the whole exchanger, for although the whole exchanger may show 50% earnings, the last square foot of that exchanger may show only 5% earnings. In this situation it is clear that if the whole exchanger pays out in two years, the last surface added would require 20 years to pay out! It would not be reasonable to request management for additional money which would require 20 years to pay out, even though the whole exchanger would pay out in two years. This is because of the extremely high profit rate for the initial surface of a heat exchanger. Large profits on the total unit sometimes tend to obscure the unprofitability of the last incremental portion added.

Earnings are defined as returns minus operating costs, taxes, maintenance, and insurance. The rate of earnings for the whole unit is E/C, where E is the earnings for a stipulated period and C is the capital. However, when looking for efficiency improvements, we have shown above that E/C does not apply, but the criterion is dE/dC. If the policy is established that dE/dC should equal 0.2, then the incremental payout is five years.

Heat Exchanger Example

A more or less classical example of heat exchanger economics is the ordinary feed-product exchanger. The simplified flow is shown in Figure 4. The entering feed exchanges against the product from the processing unit and goes to the first heater. The product passes from the exchanger through a cooler into subsequent processing. Thus, the heat exchanger at this point affects the size of the first heater and the size of the product cooler.

In Table 1 the total of exchanger and cooler surface is given for several exchanger outlet temperatures, together with the corresponding heater absorption rates and cooling water rates. For each of these cases the total capital is given with corresponding yearly utility costs and fixed charges. The earnings curve for this exchanger is shown in Figure 3. On this curve the point $dE/dC = 0.2$, for the five-year incremental payout, is shown. This point corresponds to 810° F. exchanger outlet for the feed. This establishes the optimum

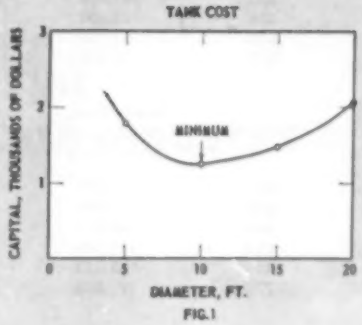

FIG. 1

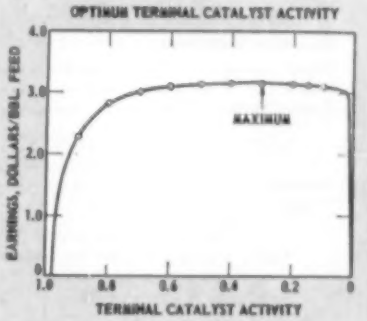

FIG. 2

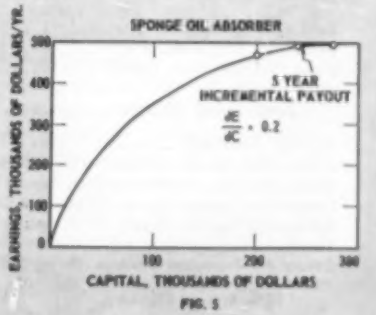

FIG. 3

Table 1.—Economics of a Heat-Exchanger Combination

Feed Out Exchanger ° F.	Total Exchange Surface sq.ft.	Heater Absorption 10^6 B.t.u./hr.	Cooling Water gal./min.	Total Capital Expense
875	227,000	36	2060	$2,160,300
860	123,300	43.5	2480	1,403,300
850	101,550	51	2740	1,272,090
825	65,500	63	3420	1,062,900
800	45,700	75	4080	969,500
775	35,600	86.3	4760	942,700

	Yearly Fuel, Power, and Water Costs	Yearly Fixed Charges 10% on Capital	Total Yearly Expense	Net Exchanger Earnings
875	$ 74,270	$216,030	$290,300	$—18,880
860	89,700	140,330	230,030	41,390
850	104,300	127,210	231,510	39,910
825	129,100	106,290	235,390	36,030
800	153,650	96,950	250,600	20,820
775	177,150	94,270	271,420	0

Table 2.—Economics of a Fractionating Tower—Sponge Oil Absorber

Recovery Values	10 Tray	20 Tray	30 Tray
Gasoline Loss, B/D	42.0	21.4	16.8
Gasoline Recovery, B/D [1]	402.0	422.6	427.2
Net Value Gasoline Recovery/Year [2]	$497,000	$523,000	$529,000
Operating Costs/Year			
Steam	$ 6,300	$ 6,300	$ 6,300
Water	2,000	2,000	2,000
Fixed Charges, 10%	19,900	23,900	27,400
Total	$ 28,200	$ 32,200	$ 35,700
Earnings/Year	$468,800	$490,800	$493,300
Capital	$199,000	$239,000	$274,000

[1] As against no absorber.
[2] After crediting dry gas for fuel values.

Table 3.—Comparison of Costs of Various Heaters

	Simple	Oil Convection	Rotary Air Preheater
Absorption, 10^6 Bt.u./hr.	73.5	73.5	73.5
Liberation, 10^6 B.t.u./hr.	127.0	114.0	96.5
Thermal Efficiency, %	57.9	64.5	76.1
Fuel Cost @ 33¢/10^6 B.t.u./yr.[1]	$349,000	$313,000	$265,000
Power, @ 1.1¢/kwhr. $/yr.[1]	.....	.....	8,834
Fixed Charges, $/yr. (10%)	39,900	47,270	60,500
Total Yearly Charges	$388,900	$360,270	$334,334
Capital (installed)	$399,000	$472,700	$605,000
Differential Capital Convection Less Simple		$ 73,700	
Yearly Earnings, Convection Over Simple		$ 28,630	
Convection Savings, % on Differential Cost/yr.		39%	
Differential Capital, Rotary Air Preheater Less Convection			$132,300
Yearly Earnings, Rotary Air Preheater Over Convection			$ 25,936
Rotary Air Preheater Savings, % on Differential Cost/yr.			20%

[1] 95% Stream Efficiency.

profit point for operations, and thus sets the sizes of the exchanger, heater, and cooler for a five-year incremental payout rate. At a three-year incremental payout rate, $dE/dC = 0.333$, and a smaller exchanger would be selected.

Sponge Oil Example

Another example is the economics of a sponge oil absorber. In this case it is necessary to balance the charge for equipment operating expenses and fixed charges against the value of the material recovered in the absorber as the number of trays is varied. This balance is shown in Table 2.

In this type of operation, a large part of the recovery is accomplished in the first few trays, so that the gasoline loss decreases relatively slowly as the trays are increased from 10 to 30. The earnings rate curve is shown in Figure 5. In spite of the very high total earning rate exhibited by this type of equipment, the optimum does not occur until about 20 trays are installed. And it is important to note that although total earnings are at a high level, the installation of trays above $dE/dC = 0.2$, as shown in Figure 5, would require more than five years for the additional trays to pay out.

Heater Example

In the selection of heaters, the matter of efficiency is paramount. There is a fairly large variety of heater types to choose from, such as simple heaters, heaters with oil economizers, steam economizers, static air preheaters, rotary air preheaters, box heaters, cylindrical heaters, etc. This example is based on the comparison of three types. The simple heater without any form of secondary heat recovery is compared in Table 3 to a heater containing an oil convection section and to a similar heater having a rotary air preheater. The thermal efficiencies of these heaters increase in order from 55% to 65 and 76%. The money spent for the convection type of heater over and above that for the simple heater will earn at the rate of 39% per year, while the money spent for the heater with rotary air preheater over the cost of the convection type of heater will earn at a rate of 20% per year.

Conclusion

From these examples it can be seen that in complex units the profitability of the whole unit should not be permitted to obscure deviations from maximum profitability of the parts. The individual parts, such as fractionators, exchangers, heaters, etc., have an optimum profitability more or less independent of the complete unit.

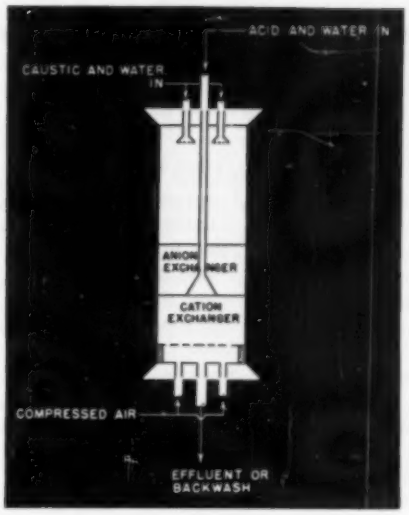

Fig. 1.

ion exchange

IN THE FINE CHEMICALS INDUSTRY

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The use of ion exchange in the fine chemicals industry is of interest both because of the diversity of the chemical compounds and of the ion-exchange resin applications encountered. Ion exchange is used, for example, in the processing of antibiotics such as streptomycin, neomycin, and penicillin, for vitamins such as vitamin B_1, vitamin C, and vitamin B_{12}, and for amino acids and polypeptides. Its operations include deionization, neutralization, ion interchange, and adsorption elution.

As selected illustrations of the use of ion exchange in the fine chemicals industry this paper discusses deionization as applied to the desalting of proteins, neutralization as applied to the removal of excess sulfuric acid from amino acid hydrolyses, ion interchange as applied to vitamin B, and adsorption elution as applied to streptomycin and neomycin processing.

Desalting of Proteins

A typical example of deionization in the fine chemical field is the removal of a sodium chloride contaminant from protein solutions. In theory this example is the same as in the treatment of water, with a cation-exchange resin of the sulfonic acid type on the hydrogen cycle to remove the sodium ions, and with a strong basic anion-exchange resin of the quaternary ammonium type on the hydroxyl cycle for the removal of the chloride ion. However, if this operation were carried out as a two-stage process with the cation-exchange resin first, the effluent from this column would be strongly acidic and would result in denaturization of the protein. A means of circumventing this difficulty has been developed recently by the use of mixed bed, or monobed, techniques, described by Kunin and McGarvey (*4*). In these mixed-bed operations it is possible to control the *p*H within a few tenths of a *p*H unit by a proper balance of cation- and anion-exchange resins.

As should be obvious from the term monobed, the cation- and anion-exchange resins are intermixed in a single column, with the resultant effect that as soon as a cation is exchanged with the liberation of a hydrogen ion, the hydrogen ion combines with the liberated hydroxyl ion from the adjacent anion-exchange resin, and the resultant *p*H remains close to neutrality.

For regeneration the mixed resin bed is backwashed with water to fluidize the bed and effect a separation of the two resins. This separation will be more complete the greater the difference in the hydraulic characteristics of the two resins. Therefore, it is essential that the two resins have different densities and/or particle size. Following separation of the resins, they are regenerated individually by passing an acid through the portion of the bed occupied by the cation exchanger, and passing caustic through the portion occupied by the anion exchanger. After appropriate washing of each resin, the bed is again mixed, usually by injection of air into the column. A typical apparatus for this operation is shown schematically in Figure 1.

Generally, a strong-acid and strong-base type of exchanger is used in monobed operations in order to get complete removal of ions. However, if some leakage of ions can be tolerated, it may prove more economical to use a strong acid-weak base system since the weak-base exchanger, while possessing a capacity equivalent to or better than the strong-base exchanger, can be regenerated with ammonia at about 110% of stoichiometric quantity, whereas the strong-base exchanger requires far greater than the theoretical amount of the more costly sodium hydroxide.

There is one major limitation to the use of ion exchange for deionization of fine chemicals; that is, that it cannot be used where the fine chemical product itself is sufficiently ionized that appreciable quantities will be lost by adsorption of it on the resin. For example, removal of salt from vitamin B_1 (thiamine hydrochloride) would be impracticable since large quantities of the ionic vitamin would adsorb on the resin.

Neutralization

The importance of ion-exchange resins for neutralization arises from the fact that no salts are introduced into the solution. The equations for this neutralization illustrate this point:

$$H^+ + X^- + R - OH \rightarrow R - X + HOH$$
$$R'^+ + OH^- + R - H \rightarrow \rightarrow R - R' + HOH$$

It should be pointed out, however, that this avoidance of salt formation is the only major advantage, and one should not look for an economic advantage since the resins must be regenerated with acids or bases, and in the cases where strong acid or base resins are used, quantities of regenerants in excess of the theoretical are required. Thus, chemical requirements will probably be greater than those if direct neutralization were employed.

For the neutralization of bases the strong-acid resins of the sulfonic acid type, are generally required to effect complete neutralization. With the carboxylic-type cation exchangers, the *p*H of the effluent from the column is still *p*H 8 to 9 when neutralization of a base is required.

For the neutralization of acids the weak-base anion exchangers of the amine type are generally used since they have two advantages over the

quaternary ammonium-type resins. First, the acid-neutralizing capacity of the weak-base resins is at least twice that of the strong-base resins. Second, regeneration of the weak-base resins is far more efficient, as pointed out earlier.

A typical example of this application in the pharmaceutical field is the removal of excess sulfuric acid from amino acid hydrolyses, where it is essential that the final amino acid solution be sufficiently pure for parenteral administration. A series of patents (*1*) describes several methods for the preparation of such solutions free of undesirable dicarboxylic acids and toxic impurities from casein hydrolysis. Casein is hydrolyzed with strong sulfuric acid at reflux. The hydrolysate solution is then diluted with water and passed in series through a column containing Ionac A300 on the hydroxyl cycle and through a second column containing Amberlite IR-120 on the hydrogen cycle. Feeding is continued until the pH of the effluent from the Ionac A300 resin has decreased to 9.0, and then both resins are washed with water. The excess sulfuric acid from the hydrolysis, as well as the undesirable dicarboxylic amino acids, are adsorbed on the Ionac A300 resin. The remainder of the amino acids are adsorbed on the Amberlite IR-120 resin from which they are eluted with aqueous ammonia. The effluent is further purified as follows:

> The effluent is concentrated, acidified and charcoal treated for removal of tyrosine. The solution is then passed in series over three ion exchangers for removal of histamine (Zeokarb H), undesirable anions (Amberlite IR4B acetate cycle), and heavy metals (Amberlite IR4B hydroxyl cycle). The solution is then adjusted in pH, treated with stabilizers, fortified with tryptophane (lost during hydrolysis of the protein) and finally autoclaved for sterilization.

Ion Interchange

As in the case of deionization, the most widely known use of the ion-interchange principle is in the water-treatment field, where the calcium and magnesium ions of hard water are exchanged for sodium ions. In the fine chemical field ion interchange reactions are important for the metathesis of pharmaceutically important organic acids and bases, as typified by the following reactions:

$$\text{Na-penicillin} + \text{R} - \text{K} \rightarrow \text{K-penicillin} + \text{R} - \text{Na}$$

$$\text{thiamine-Br} + \text{R} - \text{NO}_3 \rightarrow \text{thiamine-NO}_3 + \text{R} - \text{Br}$$

In contrast to the uses of ion-exchange resins previously discussed where it was desirable for the fine chemical to be essentially nonionic to avoid adsorption of the product on the resin, ion-interchange reactions, by their very nature, depend upon the ionic nature of the fine chemical to be processed.

Generally, for the interchange of anions the weakly basic, tertiary, or mixed amine, anion-exchange resins are employed. For the interchange of cations, the strongly acidic, sulfonic, cation exchangers are used. One limitation to the use of resins for this ion interchange is the relative affinity of the particular resin for the pair of ions involved in a given reaction. One often-cited example is the chloride-sulfate interchange. The weakly basic exchangers have a greater affinity for the sulfate ion than for the chloride ion, so it would appear obvious that the interchange from sulfate to chloride would proceed well, while the reverse reaction, from chloride to sulfate, would be highly inefficient. There are two methods of circumventing this apparent difficulty. This stronger affinity for sulfate ions is marked in dilute solutions but is greatly diminished in concentrated solutions. If dilute solutions must be used, the strong, base-type anion-exchange resins can often be made to work since these resins show much less preferential affinity for particular ions. With cation exchangers, this affinity is very pronounced in the instance of the carboxylic resins which have a very strong affinity for hydrogen ions. Carboxylic cation-exchange resins cannot be used for the exchange of hydrogen ions for sodium and potassium ions from solutions, even if the latter are present in high concentrations. Once again, however, this limitation is not serious since the sulfonic acid cation exchangers are generally suitable for interchange of hydrogen ions.

A typical example of the use of ion-interchange reactions in the fine chemical field is in the processing of vitamin B_1. This application is discussed in a patent (*2*). The salts of vitamin B_1 which are commercially used are the thiamine nitrate or chloride, and certain commercial syntheses of the vitamin produce the compound in the form of the hydrobromide salt of thiamine bromide. The ion interchange from the bromide to the nitrate or to the chloride is easily carried out by passing an aqueous solution of the bromide salt over a resin column containing Amberlite IR4B or Ionac A300 on the appropriate nitrate or chloride cycle. Feeding of the solution across the resin column is continued until the presence of bromide ion is detected in the effluent. The bromide free effluent is crystallized to yield the desired salt. In order to obtain maximum efficiency of the resin exchanger, further effluent is withdrawn from the column. This contains at first only small amounts of the bromide ion as a contaminant along with the desired salt. The small traces of bromide ion in additional effluent are removed by passing this solution over a second resin column on the appropriate cycle. When the bromide concentration in the effluent becomes too high, the first column must be regenerated before further use.

The economic advantage of this resin ion-interchange process is apparent when it is compared with the previous commercial method of effecting this metathesis which employed the appropriate silver salt. Following the metathesis, the solution had to be filtered, and silver-recovery operations had to be incorporated into the process.

Adsorption Elution

The adsorption-elution application of ion-exchange resins in the pharmaceutical field is best typified by its use in streptomycin processing. The chemical equations for this reaction may be written:

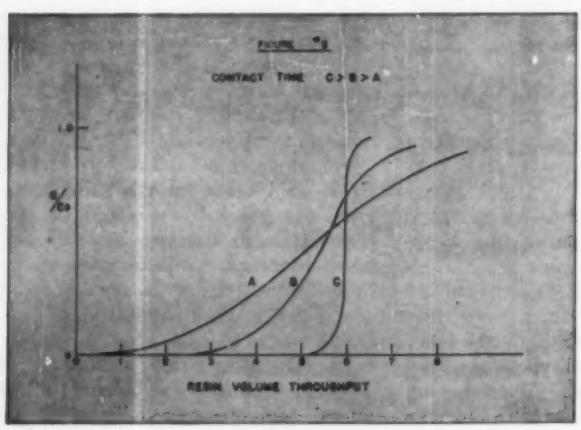

Fig. 2.

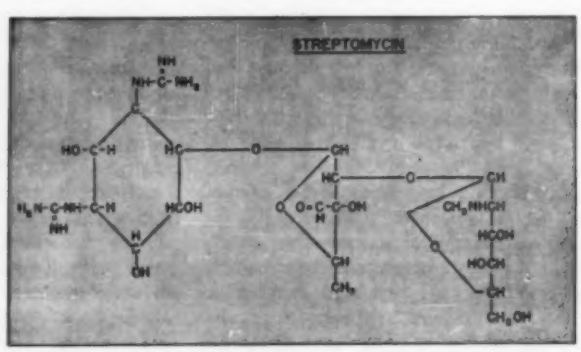

Fig. 3.

$$3R - Na + \text{streptomycin}^{+++} \rightarrow R_3\text{-streptomycin}^{+++} + 3Na^+$$

for the adsorption, and then for the elution

$$R_3\text{-streptomycin} + 3H^+ \rightarrow \text{streptomycin}^{+++} + 3R - H$$

Generally, any compound which is ionic in nature is isolable from dilute solutions or from complex mixtures with other products by use of the adsorption-elution principle. Amino acids, peptides, proteins, ionic vitamins, ionic antibiotics and alkaloids are amenable to isolation from their natural sources by use of ion exchange. In contrast, nonionic compounds such as alcohols, sterols, and hydrocarbons cannot be isolated by this technique. For example, vitamin A, vitamin D, and carotenes are not recovered from their natural sources by ion-exchange operations. An important exception in the case of nonionic compounds is that in which the compound can be converted to an ionic form by formation of a complex; sugars, for example, may be adsorbed on anion exchange resins as their borate complexes (*3*).

That the compound be ionic in nature is only one of the desirable properties of a compound for it to be practicable to apply adsorption elution to its isolation. The others are water solubility, relatively low molecular weight, and stability in acids and bases, but just as there is an exception to the ionic requirement so there are exceptions to these. Water solubility is not a strict requirement; in many cases an aqueous-organic solvent mixture can be used. The use of ion-exchange resins for removing organic impurities from gasoline indicates that water solubility is not a rigid requirement. The limit of low molecular weight has now reached the range of at least 15,000 in the case of polypeptides, and even several million in the field of virus adsorption. However, at these higher molecular weights, the adsorption is strictly at the surface and the resin capacity is limited to that exchange which occurs at the surface. The desirability of stability in acids and bases arises from the fact that most of the elutions are performed by feeding acids or bases to the resin, but even if instability is a problem, this can sometimes be circumvented by elution with salt solutions.

Of all the applications in the fine chemical industry thus far discussed, use of ion exchange, and more specifically, the adsorption-elution principle in the processing of the antibiotics is by far the major application. These antibiotics are generally produced in concentrations in the order of a few milligrams per milliliter of fermentation broth, along with high concentrations of the fermentation nutrients such as corn steep liquor, soybean meal, or casein hydrolysate. The isolation of these antibiotics in crystalline form from these fermentation liquors has been a difficult problem. Since a number of these antibiotics are ionic in nature, the adsorption-elution technique has proven to be a key step in their isolation. Of the major antibiotics, two—streptomycin and neomycin—are isolated commercially with the use of ion exchange as the major step. Streptomycin was produced at a level of 187,000 kg. in the United States in 1953, and thus, the use of ion exchange in the isolation of streptomycin represents the largest single use in the fine chemical industry. The application of ion exchange to the isolation of penicillin has been the subject of much study but the current commercial process is one of solvent extraction. Chlorotetracycline (Aureomycin) and oxytetracyline (Terramycin) are recovered using precipitation techniques and chloramphenicol (chloromycetin) is now largely produced by synthetic methods.

The structure of the streptomycin molecule is shown in Figure 3. It can be seen that it contains two strongly basic and one weakly basic group, suggesting that adsorption on ion-exchange resins should be attractive. Adsorption on the strongly acidic sulfonic acid resins occurs easily, but elution results in poor yields. Best elutions are achieved with mineral acids, and the efficiency of the elution is increased with increasing concentrations of the acid. However, streptomycin is quite unstable in strongly acidic solutions and is readily decomposed below *p*H 1, thus rendering this method of elution impractical. The adsorbed streptomycin is poorly eluted by use of sodium or calcium salts. The difficulty of instability in acid elutions can be overcome by use of the silicic acid resin Decalso from which the adsorbed streptomycin can be eluted with a 2% aqueous salt solution, but an impractical amount of salt solution is required to remove completely the antibiotic from the resin. However, since elution from the weaker acid resin Decalso could be achieved with salts, while elution from the sulfonic resins required high acid concentrations, the use of the weakly acidic carboxylic resins was suggested. When the resin Amberlite IRC-50 became available in experimental quantities in 1947, it was immediately applied to the streptomycin isolation problem and was found to have an extremely high adsorptive capacity. Furthermore, it was found that the antibiotic could be eluted quantitatively in a highly purified state by the use of dilute mineral acids. Carboxylic acid resins such as Duolite CS100 and Permutit H show similar performances in the adsorption of streptomycin.

Process Development

In the development of an adsorption-elution process, there are three points which are generally desired to be known: (1) the capacity of the resin, (2) the percentage recovery across the adsorption elution and, (3) the purification factor achieved. These data are usually collected in the laboratory by the use of small resin columns and the data are then extrapolated, and generally with considerable success, to plant-scale operations.

With the streptomycin process as an example, the steps involved are as follows:

The resin is converted to the sodium form and is washed. The streptomycin fermentation broth is filtered to remove the microorganisms, and the resultant filtered broth is then fed to the resin column by gravity flow. The flow rate is controlled to be constant and the time the broth is in contact with the resin is known. The flow rate is extrapolated to plant-scale operations by knowing this "contact time," Z/G, where Z represents the total volume occupied by the resin in milliliters and G represents the flow rate in milliliters per minute. The words "contact time" are perhaps a misnomer, since Z includes the voids in the resin column. A more precise calculation would take into account these voids, but this is usually inconvenient and not essential for extrapolations. For most ion-exchange operations of the adsorption-elution type, a pseudo contact time of 5 to 20 min. is most efficient to accomplish maximum adsorption in a minimum operational time.

To determine the optimum contact time and the quantity of broth which can be fed to a column before elution and regeneration, a laboratory column, about 1 in. in diam. and filled with about 50 to 100 ml. of resin, is generally used. Filtered broth is fed to the column and periodic samples of the "spent broth" are collected and analyzed. This is usually carried out at various contact time between 5 and 50 min. Plots are then made of the effluent concentration, c, divided by the feed concentration, c_o, against volume throughput (Figure 2). Typical S curves are obtained and the breakpoint becomes sharper as the contact time is increased. Based on economic evaluations, an allowable break concentration is selected—this is generally chosen on the basis of cumulative loss although one could select a point at which a given percentage of the feed starts to break through. Then, based on a comparison of operating costs and production capacity, one selects the contact time which is optimum for any specific case. With carefully collected laboratory data it is possible to extrapolate to any commercial size column and, feeding the broth at the chosen contact time, continue feeding until the volume throughput equals that given by the graph at the desired breakpoint.

Referring again to the graph of c/c_o vs. throughput, (Figure 2), it is obvious that the amount of streptomycin adsorbed on a given volume of resin (the resin adsorptive capacity) is also affected by the choice of contact time.

Table 1.—Effect of Contact Time on Adsorptive Capacity

Pseudo Contact time, min.	Adsorption Loading mg./ml.	Breakthrough %
0.2	60	0.5
0.2	109	9.0
1.0	179	0.5
1.0	240	9.0
6.0	272	0.5
6.0	350	9.0

The capacity of a carboxylic resin for streptomycin can run as high as 1 g. streptomycin hydrochloride per gram of resin, or 1 g./3 ml. resin. However, this is attained only if streptomycin broth is fed continually through the resin until the effluent concentration is equal to that of the feed. In actual practice, this capacity is measured under conditions where only a few per cent of the streptomycin are found in the effluent. These practical adsorption loadings usually run in the range of a few hundred milligrams of free streptomycin base per milliliter of resin.

The effect of contact time on the adsorptive capacity is shown in Table 1. The contact time is not the only thing which affects this adsorptive loading. The presence of competing cations, such as calcium, magnesium, aluminum, and iron markedly affect the loading as shown in Table 2. However, this effect can be overcome often by the addition of suitable materials to the broth to precipitate the offending cation prior to broth filtration.

The adsorptive loading is also markedly affected by the pH of the feed and this effect must be studied on the laboratory columns as was the effect of contact time and throughput. The pH range of 6 to 8 is optimum for adsorption of streptomycin.

When all these points have been studied and optimum conditions decided upon, it remains to determine the optimum method of elution of the antibiotic from the resin. After the desired volume of broth has been fed to the resin, it is followed with a water wash and then the resin is ready for elution. In the case of streptomycin, the elution is carried out with aqueous hydrochloric acid, 0.5 to 2.0 normal. The contact time for elution is generally a few fold slower than that for adsorption in order to obtain a sharply defined "rich cut." In the case of streptomycin, the eluate, in the main, comes off between pH 4.5-6.0 and is followed by a sharp drop in pH which signals the end of the elution. The rich eluate is then further processed, and the resin is water washed and regenerated to the proper cycle for the next adsorption.

In the laboratory it is necessary to study the effect of various eluting agents with respect to their yield of the adsorbed antibiotic in the eluate and the purification factor attained. The strength of the eluting solution must be dependent on two factors: the stability of the antibiotic and the volume of "rich cut." In the case of streptomycin, a low pH results in degradation and loss in yield, as mentioned earlier, but by the use of acid in the concentration range 0.5 to 2.0 normal, the acid is neutralized at the flow front and the eluted product moves down the column in a relatively neutral zone. Increasing the acid concentration increases the chance of degradation by any strong acid which tends to channel through the resin.

The purification factor should also be considered in the choice of the eluting agent. It is sometimes possible to find eluting agents which are more selective for removing the antibiotic than for removing the impurities which are also adsorbed on the resin, and thus these agents effect a purification above that achieved by the adsorption alone. The purifications achieved by adsorption elution are often very striking. In the case of streptomycin a purity increase of thirty- to fifty-fold is obtained from fermentation broth to the resin eluate.

As mentioned earlier, the antibiotic neomycin is also isolated from fermentation broth quite readily by an adsorption-elution technique which is similar to that for streptomycin. Recently, however, it was reported by Nager (*5*) that neomycin can be eluted from a carboxylic-type resin with 1N ammonium hydroxide, and that in the process, the sodium ions not replaced by neomycin are not removed. The resultant eluate can be merely concentrated to remove the ammonia and the neomycin in the effluent is in a relatively pure form. As pointed out by Nager, the ammoniacal eluate is preferably passed over a strongly basic anion exchange resin (IRA-400) which effects a considerable removal of excess color. The neomycin passes through the resin and the effluent solution is then concentrated to remove ammonia, sulfuric acid is added, and the neomycin is precipitated as the sulfate by addition of methanol.

The difference between the ability of ammonia to elute neomycin but not streptomycin is undoubtedly related to the basic strength of the two compounds. The pK values for the basic groups of streptomycin are 12, 12, and 7.8, and for neomycin the pK values of all four basic groups are about 7.8. Hence, in the presence of 1N ammonia, neomycin is 99% in the form of the unionized free amine and is easily washed off of the resin. In the case of the streptomycin molecule, however, there is no appreciable decrease in the number of moles in the ionized form at pH 11 and removal of the antibiotic can be effected only by displacement with ammonium ions. Since elution does not occur, it must be concluded that the resin has a higher affinity for the polyvalent streptomycin ion.

Table 2.—Effect of Competing Cations

(Streptomycin concentration, 1.32 mg./ml.; cation concentration, 50 p.p.m.)

	Control	Ca^{++}	Mg^{++}	Al^{+++}	Fe^{+++}
Adsorption loading mg./ml.	215	110	110	88	66
% breakthrough	0.7	0.6	0.6	0.6	0.5

Summary

Ion-exchange resins can be used in the processing of many fine chemicals in a variety of ways—in neutralization, deionization, ion interchange, adsorption elution, and also for decolorization as in the case of neomycin. The use of these resins often results in a process which is far more economical than alternate procedures, and often supplies the simple key to solving difficult isolation and purification problems.

Acknowledgment

Acknowledgment is given for the interest of R. G. Denkewalter, whose chapter on *Pharmaceutical and Biological Processes* in the forthcoming book "Ion Exchange Technology" was used as a reference.

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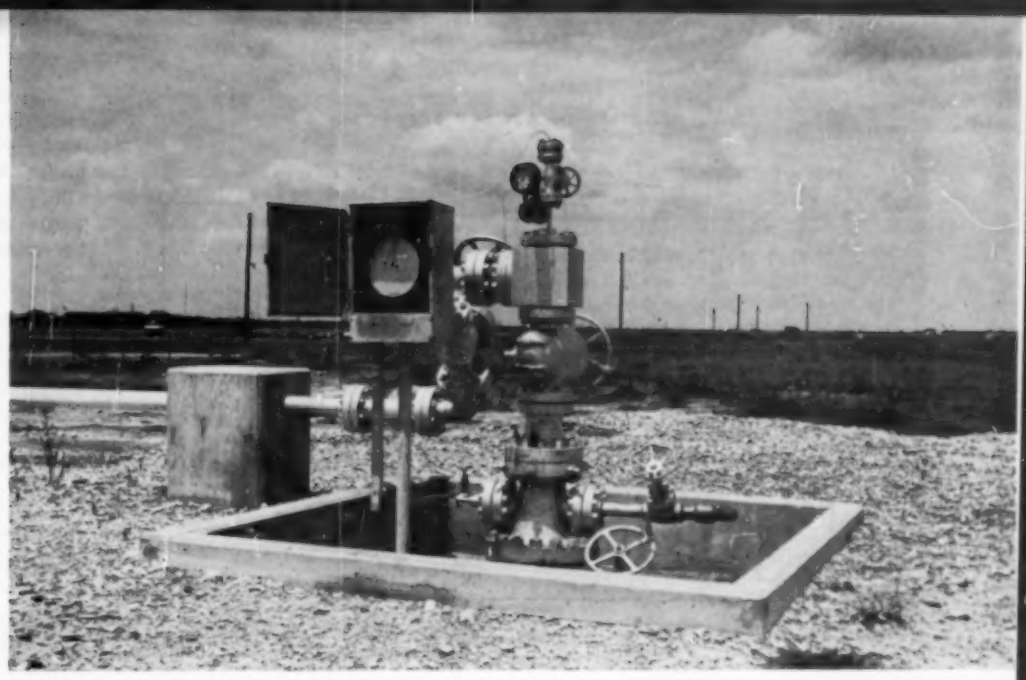

Fig. 4. No. 2 disposal well.

deep-well disposal OF CHEMICAL WASTES

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Victoria, Texas

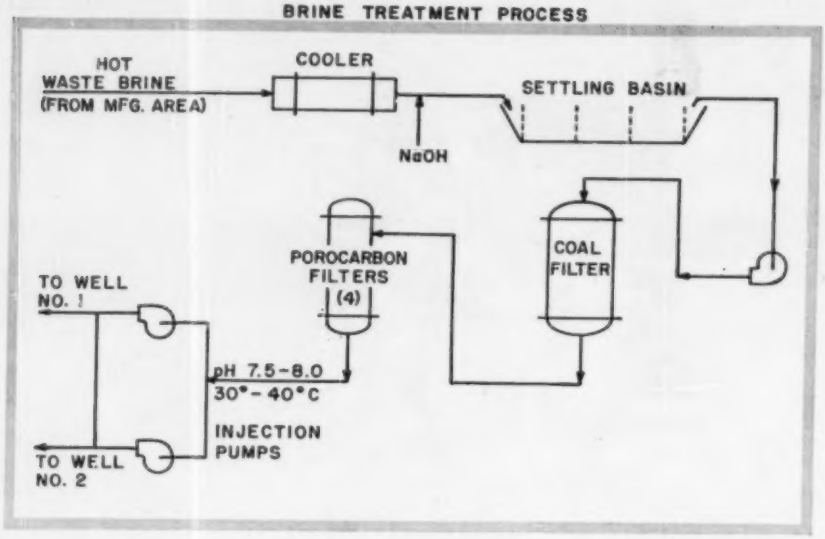
In 1951 the Du Pont Company started operations at its Victoria plant, which produces adiponitrile–an intermediate for nylon. This plant, located on the banks of the Guadalupe River a few miles south of Victoria, Texas, is like other industrial plants in that it produces wastes which must be disposed of. The majority of these wastes can and are being handled by established disposal methods. On the other hand, some of these presented special problems such that new ways had to be devised to insure adequate disposal. One of these new waste disposal methods, new to Du Pont, was subsurface disposal through injection wells.

Origin and Disposition of Waste

The purpose of this paper is to give some background on the nature of the waste stream being put underground, and to explain why the Du Pont Company decided to use this means of disposal. This waste, a purged by-product stream, is an aqueous concentrated sodium chloride brine containing small amounts of dissolved metallic salts and organic compounds. The flow of this waste brine is in the range of 100 to 150 gal./min., or about 1 tank car/hr.

In studying various means of disposing of this brine, the company considered solar evaporation and submerged combustion, but the high salt concentration made these methods unattractive. Also, piping or barging the brine out into the Gulf of Mexico did not appear economically feasible. Hence a system of underground disposal was devised; and the program for putting wastes underground was undertaken with the approval and encouragement of Texas state authorities, whose interest in the project proved helpful. These people include the Texas State Department of Health, Board of Water Engineers, Railroad Commission, and Game and Fish Commission.

Although little precedent has been available for the subsurface disposal of chemical plant wastes, a close analogy can be found in the established practice of salt-water injection in oil-field operations. Unlike oil-field brines, how-



▲ Fig. 1. Brine treatment process.

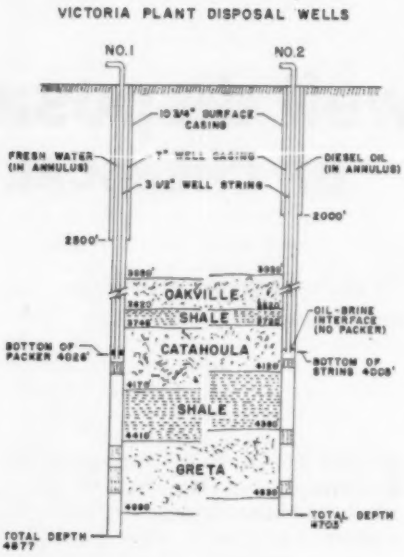
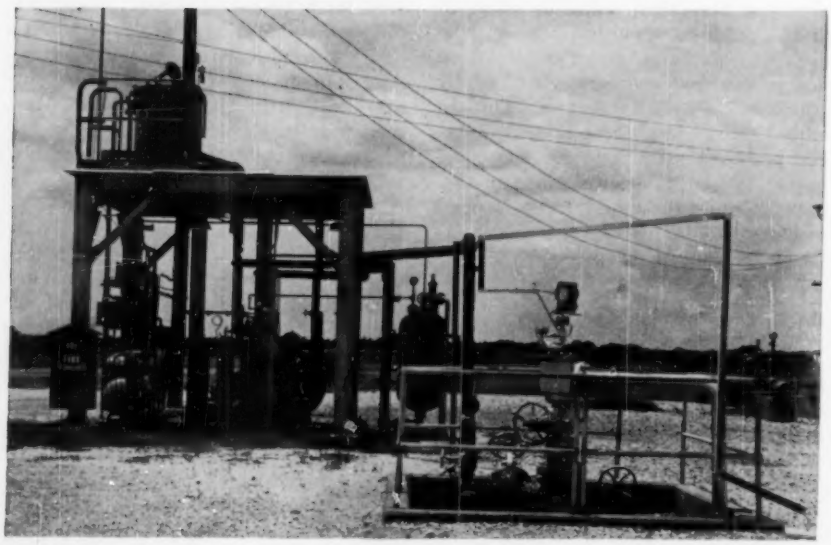


Fig. 2. Victoria plant disposal wells. ►

▼ Fig. 3. No. 1 disposal well; casing pressurizing equipment on left.



ever, the Victoria brine is a man-made waste which is foreign to the underground environment.

Waste Requirements for Subsurface Disposal

Before the waste brine can be injected underground, it must be free of suspended solids, stable, and unreactive with the natural brine and underground sand in the well. Otherwise, precipitates would plug the well sands prematurely. These are quality standards established from oil-field experience in brine disposal.

Two criteria have been established for evaluating the quality of treated brine for underground injection. First the brine should remain free of precipitate formation while standing for at least 8 hr. at 60° C., the approximate temperature at 4,000 to 5,000 ft. below the ground surface. This stability test applies also to mixtures of treated brine and natural underground brine from the well. Precipitate, or floc formation usually has been the result of metals precipitation, or degradation of organic materials, or both. During normal operation the injected brine has usually remained free of floc for 48 hr. or longer. For the second criterion brine, when passed through sand cores from the well, should not decrease the permeability of the sand. The fineness of the well sand indicates the necessity for producing brine which is stable and free of suspended solids. For example, the screen analysis of a typical sand sample showed that nearly 100% passed through a 100-mesh screen and 20% through a 200-mesh screen.

Waste Treatment Method

The waste-brine-treatment operation at Victoria has undergone a number of changes since the plant start-up in 1951. It has evolved to a point wherein the composition of the brine is controlled now almost entirely in the manufacturing step producing the brine, hence the subsequent treatment is simply a holdup and filtration operation.

The present treatment method is shown in Figure 1. The waste brine as it leaves the manufacturing area is very hot and must be cooled in a heat exchanger. After this step, sodium hydroxide in aqueous solution is added to neutralize it. This cooled, neutralized brine is run into a baffled settling basin which provides a holdup of about 16 hr. to allow any precipitates to settle out. The brine is continuously drawn off the outlet end of the holdup basin and any remaining solids are removed in a pressure filter packed with graded anthracite-coal particles. The clear filtered

brine then is given a final polishing filtration by the use of porocarbon tube filters precoated with filter aid before being pumped into the disposal wells. These porocarbon tubes will hold back any solid particles larger than 12μ diam. Both the coal filter and the porocarbon filters are equipped with back-washing facilities. Both the injection pumps are two-stage centrifugal type, each delivering 250 gal./min. at about 1,000 ft. head. The clear brine pumped to the wells is at a pH of 7.5 to 8.0 and a temperature of 30 to 40° C.

Materials of Construction—Surface Equipment

The waste brine is quite corrosive as manifested by the materials of construction in the surface equipment.

For example, the brine cooler is made of Impervite carbon. Connecting lines are Haveg. The header to the settling basin is partly Haveg and partly rubber-lined steel. The settling basin is made of earthen dikes lined with wood. All filters and connecting lines up to the injection pumps are rubber-lined steel. The injection pumps are Hastelloy. The surface lines to the wells are partly Ampco (aluminum bronze) and partly Tube-Koted (baked on phenolic resin) steel.

Construction of Disposal Wells

A schematic diagram of the two brine disposal wells at Victoria is shown in Figure 2.

The horizontal distance separating these two wells is approximately 4,000 ft. The no. 1 well was drilled about six years ago and was completed early in 1953. and the no. 2 well was drilled and completed in 1954. During the two years of plant operation preceding the starting up of the no. 1 well, the waste brine was impounded in diked basin.

The no. 1 well is 4,877 ft. deep and the no. 2 well 4,705 ft. deep. Both wells are equipped with 10¾ in. O.D. steel surface casing. In the no. 1 well, this casing extends to a depth of 2,500 ft. and in the no. 2 well to a depth of 2,000 ft. In both wells these casings are cemented back to the surface to insure a good seal. These surface casings are required by State law to reduce the possibility of contaminating usable fresh-water supplies above the waste injection zone.

Both wells have 7-in. O.D. steel inner casings extending to their total depth. These 7-in. casings are also cemented in, and they are lined with Tube-Kote for protection against corrosion. Fitting inside the 7-in. casings of both wells are 3½ in. O.D. production strings extending to a depth of about 4,000 ft. In the no. 1 well the string is made of Ampco metal, and in the no. 2 well standard-steel tubing is used. Both well strings are protected with a lining of Tube-Kote on the inside; in the no. 2 well the steel tubing is also Tube-Koted for the bottom 200 ft. on the outside.

The major difference in the construction of the two wells is that the no. 1 well employs a standard hook wall-type packer to form the seal between the well string and the 7-in. casing, whereas the no. 2 well employs an oil seal instead of a packer. The annulus between the 3½-in. string and 7-in. casing in the no. 1 well is filled with inhibited fresh water under automatically controlled pressure. The purpose of this water filling is to exert a positive pressure on the top of the packer in excess of that exerted at the injection zone on the bottom of the packer to insure that the packer will not become unseated. Also the balancing of pressures on both sides of the string prevents collapse of the string. In the no. 2 well an oil-brine interface has the same effect as the packer but does not employ a mechanical seal. In this case diesel oil is used in the annulus, and its presence also reduces the possibility of corrosion of the steel in the annulus. As had been anticipated, the oil seal has proved to be simpler and more versatile than the packer type of seal.

Sand Formations

In both wells the waste brine is injected through the 3½-in. string and into the sand formation through perforations in the 7-in. well casing. Jet-perforating guns, employing shaped charges, and bullet guns were both used to make the perforations.

The main brine-bearing sand formations in the Du Pont wells and the zones where perforations have been made are shown in Figure 2. Geologically, the wells are quite similar. The same formations are encountered, although there are some differences in their elevations and in their thickness. At present, the main injection zone in both wells is the lower part of the Catahoula formation. In the no. 1 well the casing is perforated for a vertical distance of 52 ft. (4048-4100 ft.), and in no. 2 well for 40 ft. (4076-4116 ft.) in this zone.

Previously some of the deeper sand formations (Greta series) were perforated, as shown in Figure 2. These sands, being "tight" and less permeable than the Catahoula, did not have the required capacity for brine injection even after they were acidized.

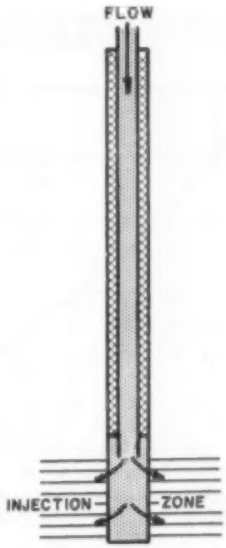
Disposal Wells

The no. 1 disposal well and casing pressurizing equipment are shown in Figure 3, the no. 2 disposal well in Figure 4.

CALCULATION OF CAPACITY

Experience in the operation of the disposal wells has been satisfactory. Performance of these wells is determined by calculating well capacity and expressing the result as an index. Figure 5 shows the formula used to obtain this index value. The index is equal to the

flow to the well divided by the net pressure forcing the brine into the sand formation. This net pressure is in turn equal to the sum of the pressures forcing the brine into the sand (well-head pressure, plus pressure exerted by the column of brine filling the well string, minus pressure drop through the string at the given flow), minus the bottom-hole pressure at the point of injection, which is an opposing force. This bottom-hole pressure was measured at static conditions and does not change appreciably. In effect, then, the index is a measure of the ability of the sand



$$\text{INDEX} = \frac{\text{BRINE FLOW}}{\left[P_{\text{HEAD}} + P_{\substack{\text{BRINE}\\\text{COLUMN}}} - \Delta P_{\text{STRING}}\right] - \left[P_{\substack{\text{BOTTOM}\\\text{HOLE}}}\right]}$$

Fig. 5. Calculation of index; the ability of the strata to take brine.

formation to receive brine, and it is roughly comparable to the permeability of the sand. This index is used to follow well performance on a day-to-day basis and it has been found reasonably reliable regardless of fluctuations in flow rate.

PERFORMANCE

Performance of the two disposal wells in terms of the aforementioned index is shown in Figure 6. The no. 1 well was started up in March, 1953. During the first year a steady decrease in index occurred, corresponding to a decrease in well capacity. This downward trend

was also reflected by an increase in well-head pressure. For example, the company was able to inject at rates as high as 100 gal./min. during the first two months with a vacuum at the well head. Vacuum occurs whenever the fluid level in the well string is below the point at which the pressure is measured. By February, 1954, about 120 lb./sq.in. gauge were required at the well head to inject 100 gal./min. of brine. The specific causes of this downward trend in capacity are still not known, but it is believed that a gradual plugging of the casing perforations, and possibly the adjacent sand itself, was taking place.

In February, and again in March, 1954, it was decided to reperforate the casing in the no. 1 well in the 52-ft. injection zone (4,048-4,100 ft.) that had been employed. This was accomplished by the use of small-diameter perforating guns that could be lowered through the well string. As hoped, an immediate increase in well capacity after each reperforating job was obtained, but this increase was only temporary. The downward trend in capacity then continued and was not arrested until June, 1954, when some process changes were made which altered the chemical composition of the waste brine. It should be noted that the index actually started to rise after this point, indicating not only that well plugging had stopped, but also that some of the previous plug had started to redissolve. This index rise apparently continued while the well was temporarily out of service.

To insure adequate well injection capacity to take care of outages and increased brine rates, a second disposal well was installed. This no. 2 well was started up in August, 1954, and its index trend is shown by the dotted line in Figure 6. During the next several months the no. 1 well was left idle. Note that the index of the no. 2 well was initially high and that it then dropped off rapidly before it began to level out. Based on experience with the no. 1 well, this initial drop is characteristic of a newly perforated well. It is believed that this drop is a normal one associated with reaching equilibrium for brine injection, and that the sharper initial drop in the no. 2 well is due to the fact that the sand strata in this well are somewhat less permeable than in the no. 1 well.

So far in 1955, both wells have shown only slight variations in index although the trend appears to be gradually downward. Whereas there is some spread between the index values for the two wells, the capacity of the wells has been about the same. This difference in index is due to differences in the inside diameters and hence pressure drop in the two well strings, and to differences in the bottom-hole pressures at the injection zones.

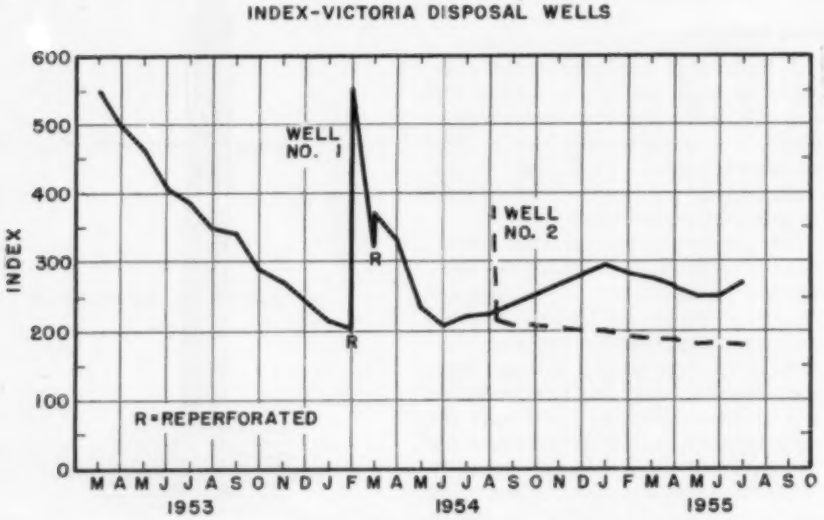


Fig. 6. Index-Victoria disposal wells.

METHOD OF OPERATION

The program of well operation is to run only one well at a time with full waste-brine load such that reworking of the wells can be staggered. The plan specifies a continuance of injecting brine into the no. 1 well until its capacity is limiting, and then have the well reworked while the no. 2 well is on the line. Actually the stand-by no. 2 well has been operating periodically in order that a check can be kept on its condition.

Some conditions that require particular attention in the operation of the disposal system are:

1. Poor stability of the injected brine causes well plugging due to the formation of precipitates. Hence everything is done to insure control of the manufacturing step, which produces the waste brine, so that there is a minimum of variation in brine composition and a minimum concentration of precipitate-forming substances.

2. Suspended solids in the brine cause well plugging. Hence there is a constant check of the polishing filters to be sure that there is no leakage of suspended solids through them.

3. Entrainment of air in the injected brine causes temporary loss of well capacity since the air results in decreased brine specific gravity and hence decreased static pressure of the brine in the well string. Also passage of the air into the well sands restricts brine flow through the sands and thereby gives the effect of well plugging. Another bad effect of air would be the oxidation of ferrous iron present in the natural underground brine, resulting in ferric iron precipitates and hence well plugging. Entrained air has occasionally entered the wells in the past and has possibly contributed to loss in capacity. Frequent checks are made to insure that air is not being entrained in the brine. To reduce the possibility of air entrainment, the preference at Du Pont is to operate the wells with flows high enough to give pressure at the well head, rather than to operate at low flow with vacuum at the well head.

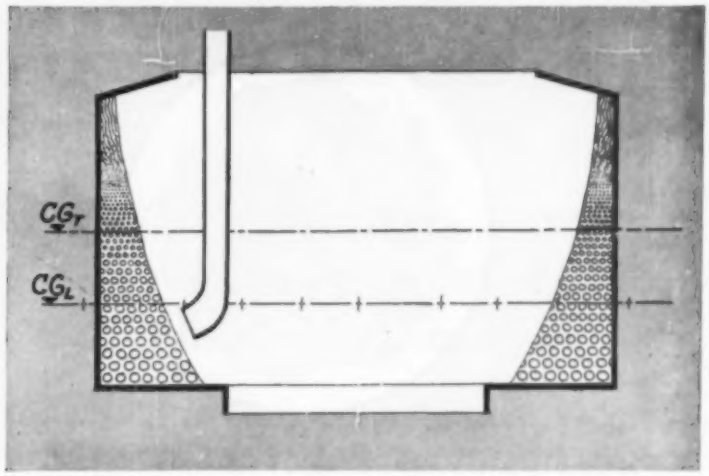
COSTS

Disposal wells are expensive, particularly if the brine is more corrosive than natural brine. The total cost of our first well, including auxiliaries, was in the neighborhood of $250,000; the second well was considerably less. The lower cost of the second well is attributed to applying experience gained in the operation of the first well. For example, the location of the pertinent sand formations was learned in drilling the first well, hence less coring and other exploratory work were done in well no. 2. Less expensive Tube-Koted steel was substituted for Ampco as the material of construction for the well string. Also the casing oil seal design in the no. 2 well was used, thereby eliminating the need for a packer and casing pressurizing equipment.

Summary

This account covers the Du Pont Company's first venture in subsurface waste disposal and relates how it has fared to date. This venture has been a successful one. During the two and one-half years that these disposal wells have been in operation, 100 million gallons of waste brine have been injected underground.

Fig. 1.



loading and washing in BASKET CENTRIFUGALS

J. A. Schneider | The Western States Machine Company, Hamilton, Ohio

Without centrifugation many modern chemical processes would not exist. This fact is becoming more evident with the new applications and increased number of investigations into the possible advantages to be derived by centrifugation over existing methods of liquid-solid separation. This paper does not disclose any startling revelations on the subject; rather is its purpose to cite the benefits of the observations which have been catalogued and which add up to the importance of many small details and considerations that make up a successful operation.

The complete centrifugation operation can be separated into the following major mechanical components:

(a) loading
(b) purging
(c) washing (if necessary)
(d) drying

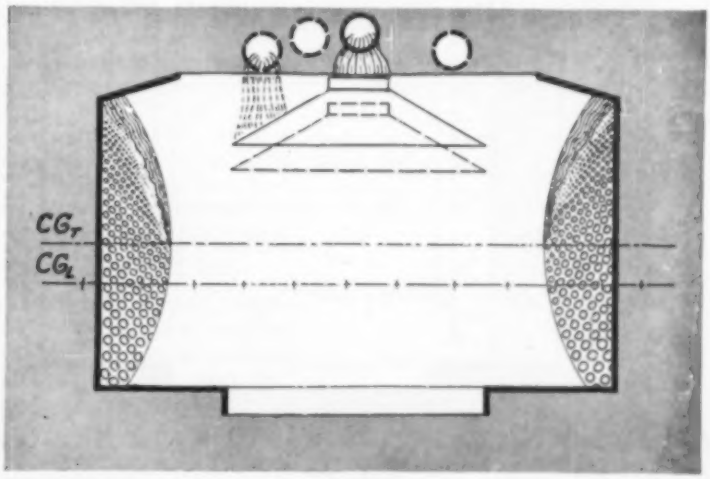
Some operations do not involve washing; however, the other three components (in the listing) are usually indicated.

Loading

No centrifugal operation can be regarded as successful with optimum results unless the material can be uniformly applied to the filtering medium. This is essential, not only to product results, but also to the stability of the machine itself. Some typical examples of improper loading are illustrated here.

The type of loading shown in Figure 1, although not seriously affecting the stability of the machine, results in lack of uniformity in the discharged cake. It also suggests classification of the solid particles. The heavier particles are deposited in the lower part of the basket, and the lighter particles–in many cases slime–are deposited in the upper area. One can observe also in this figure that the center of gravity of the load has shifted to the lower part of the basket, which has a tendency to upset the basic built-in stability of the machine. This is what is usually called a "hobo" and, from observations of hundreds of cen-

Fig. 2.



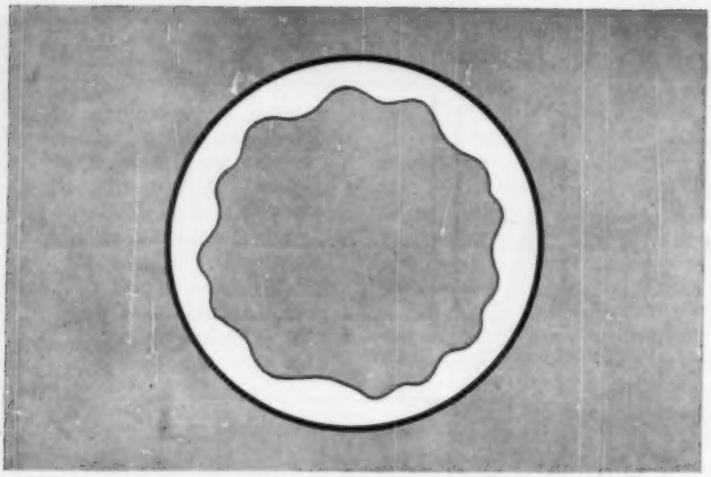


Fig. 3.

trifugal operations, is the rule and not the exception.

This type of load usually results in free purging materials of high relative density. The condition can be improved by altering the design of the loading device, or changing the rate of feed, or altering the loading speed.

The type of load in Figure 2 usually results on applications where a loading cone mounted on the rotating spindle has been employed. Again, lack of uniformity results in the discharged cake. This condition usually can be improved by altering the position and changing the angle of the cone, changing the rate of material feed, or the speed of the cone. In some instances, the angle and position of feed on the cone will show marked improvement.

Figure 3 illustrates the type of load that gives the most trouble. Again, lack of uniformity in the cake results. Also, it is practically impossible to bring the basket up to a purging or drying speed because of the unbalance in the basket. This causes the machine to vibrate quite severely, resulting in damage to the suspension head and, in many instances, causes spindle damage. This type of load is usually associated with fast purging heavy particles and suggests an adjustment in basket speed or feed rate. In some instances a leveling rake in contact with the material wall is helpful.

Figure 4 shows the ideal type of load and one which is striven for on all applications. It can be accomplished usually after a series of investigations of the loading characteristics of the material. Manifolds equipped with flooding nozzles, loading cones, and direct impingement by spray are but a few of the ingenious devices which have been developed to accomplish these conditions.

Purging

At this point, the importance of the ratio of feed to purging should be emphasized. If the feed rate exceeds the purging rate, a liquid wall builds up on the surface of the cake, causing a series of liquid shock waves, which can result in serious unbalance to the machine. Also, it produces changes in the filtering characteristics of the material. This condition is observed frequently in manual loading where the operator, because of too high a loading rate, must of necessity interrupt the loading to permit drainage of the liquid. If subsequent loading is not timed properly, a surface reaction takes place which changes the filtering characteristics of the cake.

Since the loading of the basket is the first operation in the centrifuging cycle, one cannot emphasize too strongly the benefits to be derived from a thorough investigation and consideration of this component.

Purging has been indicated as the next component in the duty cycle, immediately following the conclusion of loading. Regardless of whether washing is indicated or not, there should be a short purging time (a matter of seconds) in order to permit drainage of the mother liquor from the surface of the cake. After surface liquid has been removed, the centrifugal force can be increased by increasing the speed of the basket for the final extraction or drying of the material.

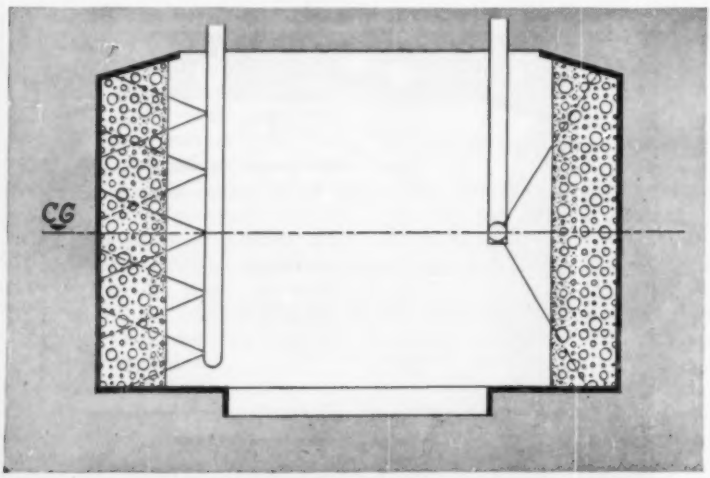


Fig. 4.

Washing

If washing is indicated, it is usually desirable to introduce the wash just as soon as the surface liquid has disappeared from the cake. When this is done, the drainage characteristics of the cake have not had an opportunity to change. In some instances a surface tension or film is set up upon disappearance of the surface liquid to a point where washing becomes difficult.

Drying

Final drying, a matter of time and centrifugal force, is usually accomplished at higher pressures, except in cases where the compressibility factor of the cake inhibits the drainage characteristics. In those cases the pressures are kept constant in order not to disturb the porosity of the cake.

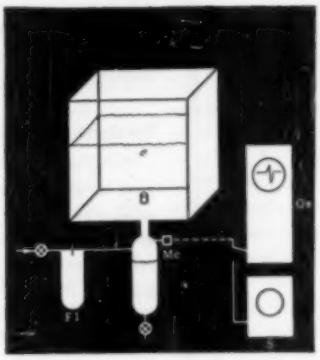
Presented at A.I.Ch.E. meeting, Louisville, Kentucky.

CORRECTION

In "Mass Transfer in a Fluidized Bed" which appeared in the March, 1953, issue of Chemical Engineering Progress page 141-49, Equation (23) was erroneous. It should read as follows:

$$G^{1.9} = \left(\frac{V}{S}\right)^{1.9} = \frac{\rho_f \epsilon^3 D_p^{1.1} \Delta\pi g_c}{2.9(1-\epsilon)^{1.1}\mu^{0.1}L}$$

Fig. 2. Diagram of equipment.



The Formation of Bubbles at Simple Orifices

R. R. Hughes, A. E. Handlos, H. D. Evans, and R. L. Maycock

Shell Development Company, Emeryville, Calif.

Fundamental correlations for estimating mass transfer, heat transfer, or pressure drop in important vapor-liquid contacting equipment such as is used in fractionation, absorption, or reaction require reliable estimates of bubble size created under various contacting conditions. However, the action of commercial contacting equipment is complex, and bubble sizes are quite difficult to measure. As a result, many authors have attempted to study the factors influencing bubble size on a simple scale (for example, the formation of bubbles from an isolated orifice) with the idea of extrapolating their findings to process conditions. The diversity of their conclusions shows that this experiment is more complex than has generally been realized. This paper reports some experimental and theoretical work, which is not yet concluded, but which already shows the nature and behavior of this complexity.

Variables Involved in Bubble Formation

1. PHYSICAL PROPERTIES OF THE GAS AND THE LIQUID

For simple fluids these are the densities, ρ_L and ρ_g, viscosities, μ_L and μ_g, the interfacial tension, σ, and the velocity of sound in the gas, c. Even though the gas velocities are low, c cannot be ignored, because nonsteady flow is inherent at some points in a bubbling system. The velocity of sound in the liquid is immaterial in almost all cases. For complex liquids such things as non-Newtonian viscosities, electrostatic surface charges, and surface activity of solutes in the liquid phase may be important. These complex liquids will not be considered here.

2. GAS MOTION

This can be introduced in terms of the average volumetric flow, q', the velocity through the opening, V_o, or the bubble frequency, ν. In general, three regions can be distinguished: very low flow rates at which formation is primarily a static problem; intermediate rates for which bubble size is dependent on flow, but individual bubbles form at the tip; and extremely high rates, where the jet of gas issues from the opening and is later broken into bubbles which are not uniform in size but represent a generalized dispersion. The present work is devoted primarily to the static and regular bubbling regions although a few qualitative experiments were made in the high rate region.

3. LIQUID MOTION

In addition to the drag due to the introduction of the bubble itself, forming bubbles are subject to drag from the liquid flowing past the forming tip. This liquid motion may be induced by (1) the rising bubble stream or (2) forced convection created by some external force. Only the first type is considered here although the second type is important when designing a gas dispersion device.

4. VESSEL CONSTRUCTION

In order to control the liquid circulation produced by the bubble stream, the vessel design should be considered. Such features as orifice diameter, outer diameter of the inlet, vessel diameter, the submergence of the orifice, asymmetry, etc., may affect bubble size by affecting liquid motion.

5. GAS INLET CONSTRUCTION

Many variations in gas inlet design are possible, but the present work is limited to simple, circular-cylindrical, vertical tips of length, L, and inside diameter, d_p. In addition to the inlet itself, the enlargements or contractions immediately behind the orifice or tip and the volume of gas, v_c, contained in any chamber close to the tip, will influence the pressure-flow rate relations of the gas supplied to the tip as well as the turbulence in the gas at the orifice.

6. ACCELERATION OF GRAVITY, g.

When the dimensional analysis is made, it is convenient to introduce in place of g the equilibrium bubble of diameter d_e, and volume:

$$v_e = \frac{\pi g_c \sigma d_p}{g(\rho_L - \rho_g)}. \qquad (1)$$

This is introduced as a first approximation (and a rough one) to the bubble volume at zero flow since it represents the case of buoyancy balanced by surface tension on the wetted perimeter.

Dimensional Analysis

A dimensional analysis of these variables produces the following functional relationship for the bubble volume, v, produced at simple tips in the regular bubbling region:

$$\frac{v}{v_e} = func\left(Re,\ N_\sigma,\ \frac{\rho_L}{\rho_g},\ \frac{\mu_L}{\mu_g},\ \frac{L}{d_p},\ \frac{d_e}{d_p},\ \frac{v_c}{v_e},\ Ma\right) \qquad (2)$$

where

$$Re = dV'\rho_L/\mu_L = q'\rho_L/\pi d\mu_L \qquad (3)$$

$$N_\sigma = g_c\sigma\rho_L d_p/\mu_L{}^2 \qquad (4)$$

$$Ma = V_o/c. \qquad (5)$$

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Figure 1, Tables 1 and 3, and supplementary material are on file (Document 4601) with A.D.I. Auxiliary Publications Project, Library of Congress, Washington, D. C. Price of microfilms is $2.75, photoprints $8.75.

Table 2.—Summary of Experiments

Liquid				Gas	Apparatus Dimensions						Flow Range				Bubble Volumes (cc.)	
					d_p(cm.)		L(cm.)		v_c(cc.)		q'(cc./sec.)		V_o(cm./sec.)			
	σ dynes/cm.	ρ_L g./cc.	μ_L(cp.)		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Water	74	0.99	~ 1.00	Dry Air	0.1067	0.1853	0.635	7.62	3.93	90.1	0.18	24.6	20	915	5.1	47	0.034	0.803
Water	74	0.99	1.00	Air Saturated w/water at 7° C.	0.1067	.....	5	....	3.93	60.6	1.328	4.75	149.5	518	8.5	36	0.0557	0.1507
Water	74	0.99	1.00	Air Saturated w/acetone at 0° C.	0.1067	.....	5	....	3.93	60.6	1.230	4.58	116	518	10	44	0.0426	0.1360
Acetone	26	0.79	0.30	Dry Air	0.1067	0.1853	5	....	3.93	90.1	0.48	22.9	52	793	9.8	58	0.026	0.606
Acetone	26	0.79	0.30	Air w/acetone	0.1067	0.1853	5	....	3.93	90.1	0.88	32.8	98	1220	14	53	0.029	0.933
Acetone-water (50% wt.)	30	0.915	1.23	Air w/acetone	0.1067	.....	5	....	3.93	60.6	1.42	5.6	159	610	14	53	0.044	0.129
15% w/Water 85% w/Glycerine	...66	1.22	81.0	Dry Air	0.1067	0.1853	5	....	3.93	60.6	1.11	22.9	43	854	6.4	36	0.085	0.917
21% w/Water 78% w/Glycerine	.. 66	1.20	32.0	Dry Air	0.1067	0.343	5	....	3.93	90.1	0.0046	32.8	0.13	3048	0.083	42	0.057	1.262
Water	74	0.99	1.00	Dry Air	0.0381	0.542	5	....	1.64	59.0	0.0022	.034	0.09	6.15	0.2	0.3	0.0108	0.1135

Various shape and roughness factors for both the vessel and the gas train should be included in Equation (2) whenever sufficient data are available.

Previous Work

Quite extensive data on regular bubbling have been reported. Unfortunately, none of the experimenters seem to recognize the importance of all the variables discussed above and few report even all the necessary data. In most cases gas train dimensions and vessel shape have been estimated from small scale drawings or photographs. Fortunately, most of the effects found depend on the order of magnitude of these dimensions. The data considered in our study are summarized in Table 1. For those cases in which sufficient information is given, a sketch of the apparatus is included in Figure 1. (Table 1 and Figure 1 are on file with the A.D.I. The discussion in the original manuscript which follows this paragraph, along with the literature cited references, are on file also with A.D.I.)

Experimental Approach

The data which are summarized in this paper were obtained in the region of regular bubble formation. Their principal contribution is the observation of the influence of the volume of the gas train below the orifice, the chamber volume, on the volume of the bubbles formed at finite rates of gas flow.

APPARATUS AND PROCEDURE

The setup which was used in obtaining these data is shown in Figure 2. The tank was a 1-ft. cube. The orifices were lengths of glass or metal capillary. The rate of flow of gas was measured with an orifice meter. The variations in pressure of the gas during the formation of the bubble were detected with a microphone button, Mc,—battery and matching transformer not shown. The output was fed to the oscilloscope. The frequency of bubble formation was measured by matching the sweep frequency against pulses from the stroboscope. The use of the oscilloscope as an intermediate record of the frequency removed some of the difficulties usually introduced by stroboscopic examination. The original intention in the use of the microphone was to examine the pressure fluctuations, but use of a strain gauge, amplifier, and Brush recorder was found to be more satisfactory for this purpose. All the data were obtained at room temperature (20° to 25° C.) with air as the gas. Table 2 is a summary of the various data obtained. Only sufficient data are given to illustrate the several variables. (Complete data are being filed with the American Documentation Institute.) In addition to these data, qualitative information was obtained from movies made at speeds up to 4,000 frames/sec.

HIGH FLOW RATE DATA

The effect of chamber volume on the volume of the bubble is shown in Figures 3 and 4 for the air-water system with orifice diameters of 0.042 and 0.073 in. Chamber volumes of 0.24,

1.2, 2.4, and 3.7 cu.in. were studied. The data points include submergences of 7.9, 5.9, 3.9, 2.0, and 0.8 in. No effect of submergence of the orifice was observed. The effect of material of the orifice was examined by comparing data from glass and brass capillaries. Typical data are shown in Figure 5. The curve is taken from Figure 4. At very low flow rates of air, the properties of the orifice are important, as will be discussed below. The influence of walls adjacent to the orifice was studied by placing tubes concentric with the orifice in the tank. Typical data are shown in Figure 6, in which no effect is apparent with a tube 3.3 in. in diam., but an appreciable effect is obtained with a tube 0.5 in. in diam. The capillaries were varied in length (3.0, 1.5, 0.75, and 0.25 in.); the data are shown in Figure 7; no significant effect was observed.

Some examples of the fluctuations in air pressure which occur in the gas train during the bubbling process are shown in Figure 8. At very low flow rates the maximum pressure difference, $4\sigma/d_p$, should occur when the bubble becomes hemispherical. Whether this is also true for bubbles which are formed at higher rates was not established. For the 0.073-in. orifice with acetone as the liquid, this maximum pressure difference should be 0.008 lb./sq.in. (two scale divisions). The orifices were wet by the liquid, however, and some of the increase in pressure difference with increase in chamber volume is a result of the kinetic head required to eject the liquid which feeds back into the orifice after each bubble is released. The amount of liquid feedback increases with chamber volume, other conditions being constant. In addition, the acceleration forces on the gas bubble contribute to the pressure difference.

LOW FLOW RATE DATA

Observation of the influence of chamber volume on the formation of bubbles at finite rates (5-45 bubbles/sec.) led to the question whether such an influence would extend to bubbles formed at much lower rates, for example, 10-20/min. At low flow rates of air the interfacial tensions of the air-liquid-solid system have significant effects on bubble size. With clean glass orifices wetted by the liquid, the initial phases of drop formation occur inside the capillary since the liquid is forced into the capillary after each bubble is released. If the orifices are made nonwettable by treatment with a silicone or similar material, the liquid does not push down into the capillary. A pronounced effect of chamber volume on the formation and volume of the bubble at low flow rates of air is now observed. Data are shown in Figure 9. With the 0.135-in. orifice, the bubble first becomes hemispherical and then grows rapidly but does not detach itself until further (slower) growth takes place. With an orifice 0.073 in. in diam., the delayed release is observed at chamber volumes less than that indicated at (a). At higher chamber volumes the growth and release from the hemispherical shape is simultaneous. With the orifice 0.028 in. in diam., the delayed and immediate releases are also observed, but in addition, at sufficiently high chamber volumes two bubbles are released simultaneously. This point is indicated by the lower case *d* on the plot. The volume per bubble is plotted in all cases of multiple bubble formation. With the smallest orifice the chamber volume could not be made small enough to observe the transition between the delayed release and the immediate release, but regions in which single, double, triple, and quadruple bubbles were formed were observed as the chamber volume was increased. The lower case letters mark these regions of multiple bubble formation. Some of the observations of Pattle (*14*) concerning double bubble formation are apparently related to these phenomena, even though he did not vary chamber volume.

Theoretical Approach

A study of the data summarized in Tables 1 and 2 showed extreme discrepancies among experiments which were superficially identical. A possible explanation is the effect of the variables which were often overlooked, the gas train dimensions, and the gas acoustic velocity. These are of prime importance in the pulsation of the gas flow. Inclusion of these variables in Equation (2) makes too unwieldy a system for direct empirical correlation. Similarly, attempts at exact theory were defeated by the complex equations needed. Accordingly, it was decided to simplify the theory as much as necessary to permit solution. This solution was then used as a qualitative description of the interaction of the variables, which provided a basis for correlation.

PHYSICAL FACTORS INVOLVED

In view of the large number of variables involved in Equation (3), it is important to choose those groups which are most significant and which bear some relation to the theoretical conclusions. As a start, the physical factors involved in this relation should be considered. For the case of individual bubbles formed at a simple inlet, these are

1. buoyancy of the bubble
2. adherence of the bubble to the tip
3. drag and turbulence of the surrounding liquid
4. oscillation and distortion
5. inertia and turbulence of the entering gas
6. fluctuations of tip pressure and flow rate

The first two factors apply primarily to the case of low gas flow rates. At higher rates, though still acting, they are less important. The other factors in one way or another arise from the kinetic effects. Thus, a theoretical study should begin with the equations of motion. Unfortunately, because of the turbulence and geometry involved, this approach is unsuccessful. It is necessary, instead, to consider the bubble as a complete entity and use over-all forces. While this is, in general, satisfactory, it has the major defect of not providing any solution for the bubble shape either during formation or upon separation. Where necessary in the following development, the shape is assumed to be that of a sphere tangent to the plane of the orifice. The error introduced is probably not severe except for very large bubbles or low surface tension and does not occur in the final correlation, which is based on experimental data.

FORCE BALANCE ON A BUBBLE

From a consideration of the factors listed above, a force balance can be made. If the bubble is considered to be all the gas above the plane of the orifice and has at any time a volume, v_t, and mean velocity, V, the force balance becomes:

$$g_c\ (\text{net buoyancy} + \text{excess pressure} - \text{drag} - \text{surface force}) = \frac{d}{dt}\ (\text{momentum})$$

$$g\Delta\rho v_t + g_c(p_t - p_p)A_o - \left(c_D A_f \frac{\rho_L V^2}{2} + b\frac{dV}{dt}\right) - \pi g_c d_p \sigma = \frac{d}{dt}(\rho_g v_t V) \qquad (6)$$

Unless forced liquid flow occurs, the liquid pressure at the orifice, p_p, is an easily calculated constant since the local variations in liquid pressure due to bubble growth are absorbed in the drag coefficient, c_D, and the carried mass, b. Since the bubble velocity, V, and the frontal area, A_f, are functions of the shape and volume, v_t, of the bubble, this equation relates p_t and v_t with t as the independent variable.

EFFECTS OF GAS SUPPLY TRAIN

The other relation between p_t, the pressure at the tip, and the volume of the pendant bubble, v_t, is obtained by a consideration of the motion of the gas upstream of the tip and the material balance for the bubble:

$$v_t = v_s + \int_{t_s}^{t} q\,dt \qquad (7)$$

The fluctuations of pressure produced by the formation of the bubble are transmitted back through the gas stream, causing fluctuations in both the volumetric flow rates and the pressures upstream. This system is readily treated in terms of an electrical analogue of the acoustic system. Figure 10 shows the bubble formation device with its electrical analogue. Pressures are made analogous to electromotive forces and flow rates are made analogous to the electrical flows or currents.

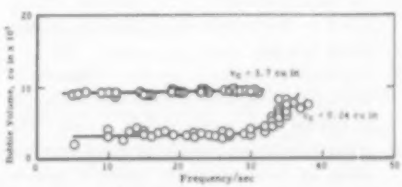


Fig. 3. Chamber volume effect. Air bubbles in water $d_o = 0.042$ in.

The chamber volume represents an acoustical capacitance where

$$C = \frac{g_c V_c}{\rho_g c^2}. \tag{8}$$

Similarly, the long tip represents a combined resistance and inertance expressed by the following terms:

$$R \equiv \frac{\overline{(p_c - p_t)}}{q} \approx \frac{8\pi}{g_c} \mu_g \frac{L}{A_o^2} \tag{9}$$

$$M \equiv \frac{L\rho_g}{g_c A_o} \tag{10}$$

In the expression for the resistance, R, Poiseuille's Law has been assumed for the gas flow. Although the electrical analog method requires that the pressure drop at the tip be proportional to the flow, the proportionality factor is not necessarily that given by Poiseuille's Law. However, the flow rates for regular bubble formation all occur with viscous flow in the tip. Assumption of Poiseuille's Law is not unreasonable although error due to short lengths may be appreciable.

By applying Kirchkoff's Laws to the electrical circuit of Figure 10, one obtains the desired relation:

$$-\frac{dp_t}{dt} = M\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q - q'}{C}. \tag{11}$$

The equation for chamber pressure, p_c, which was measured in our apparatus, is

$$-\frac{dp_c}{dt} = \frac{q - q'}{C}. \tag{12}$$

Typical amplitudes of $(q - q')$ can be calculated from Equation (12) and the data shown in Figure 8. For the small chamber volume these amplitudes were only about 2 or 3% of q', but for the large chamber volume, they are about 60% of q'.

Similar analogs can be made for more complex gas trains, but the final equation between q, p_t, and t, is usually of a higher order. Over limited frequency ranges, these equations can be approximated by Equation (11), with appropriate effective values of M, R, and C.

SOLUTION OF EQUATIONS

Equations (6), (7), and (11) can in theory be solved simultaneously to give v_t, p_t, and q as functions of t. In practice the desired analytic solution cannot be obtained because of the nonlinearity of Equation (6). As discussed above, this equation is linearized to provide a qualitative model by the following assumptions:

1. The drag coefficient, c_D, is inversely proportional to the instantaneous Reynolds number of the bubble.
2. The bubble velocity is assumed proportional to the flow rate, with no allowance for change in bubble cross section during growth. The proportionality constant is obtained from the value at breakoff for a spherical bubble tangent to the plane of the orifice, that is, $V = q/\pi d^3$.
3. The frontal area, A_f, for the drag term is assumed constant at its final value, $\pi d^2/4$. This partially counteracts assumption 2.
4. The carried mass, b, is assumed constant during bubble growth.
5. The momentum term is negligible.

In effect, these assumptions require effective values of c_D and b. For instance, much of the accelerational drag is absorbed in c_D, since, for a case of negligible flow fluctuation, even though rapid accelerations of the bubble occur, the carried mass term disappears, because of assumption 2.

With these assumptions and the specified conditions, the solution in terms of Fourier series, although lengthy, is straightforward. Because of the many parameters involved, study by the writers of the results and their application to the correlation of experimental data is not yet complete. At present they are interested primarily in correlating the data which show a negligible effect of the gas train variables. This allows evaluation of the drag effects for later study of the more complex cases. To rule out unwanted data a necessary condition is $\zeta << 1$ where

$$\zeta \equiv \frac{N_v}{2\sqrt{K}}\left[\frac{N_D}{\sqrt{K}-1}\,ctnh\,\frac{\sqrt{K}-1}{N_D} - \frac{N_D}{\sqrt{K}+1}\,ctnh\,\frac{\sqrt{K}+1}{N_D}\right] - 2N_v\left(\frac{N_D}{K-1}\right)^2 \tag{13}$$

$$K - 1 = N_D N_v\left(1 - \frac{1}{N_c}\right) \tag{14}$$

$$N_v = \frac{\left[g\Delta\rho v\right] \Big/ \left[c_D A_f \frac{\rho_L V'^2}{2}\right]}{1 + \frac{256}{C_D Re}\frac{\mu_g}{\mu_L}\frac{d}{d_p}\frac{L}{d_p}} \tag{15}$$

$$N_D = 32\,Re\,\frac{\frac{b}{\rho_L v} + 6\frac{\rho_g}{\rho_L}\frac{L}{d}}{C_D Re + 256\frac{\mu_g}{\mu_L}\frac{d}{d_p}\frac{L}{d_p}} \tag{16}$$

$$N_c = \frac{g\Delta\rho C}{g_c A_o} = \frac{g\Delta\rho v_c}{A_o \rho_g c^2} \tag{17}$$

Equation (13) is plotted in Figure 11 for typical values of N_D and N_v.

The condition $\zeta << 1$ is necessary to make the average pendant bubble volume the same as would occur for steady flow. Naturally, it is possible to satisfy this condition with an unsteady flow. However, it is more likely that unsteady flow will result in a different value of average pendant bubble volume. It seems safe to assume that all data for which $\zeta << 1$ can be correlated in terms of surface forces and drag alone.

Formation at Very Low Flow Rates

Study of bubble formation at very low flow rates is primarily of interest as a guide to the importance of the surface forces and the elimination of the direct effect of these forces by the introduction of the zero rate bubble volume, v_c. Since at *zero* rate kinetic effects cannot occur and gas train dimensions cannot affect the forming bubble, Equation (2) becomes

$$\frac{v_o}{v_c} = func\left(\frac{\rho_L}{\rho_g}, \frac{d_c}{d_p}\right) \tag{18}$$

For a cylindrical-necked bubble, $v_o = v_c$. Thus the function of Equation (18) expresses deviations in shape due to the differences in neck and bubble proportions and in the ratio of static pressure gradients inside and outside the bubble. These should be relatively minor effects, and so large variations in v_o/v_c must be due to kinetic effects always present in any actual experiment.

EFFECT OF GAS FLOW PULSATION

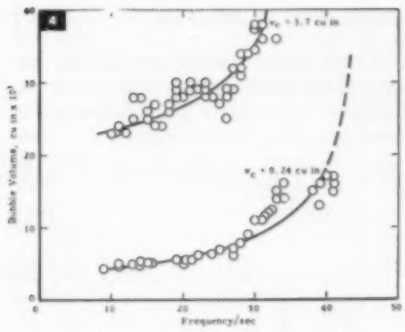
Our low flow rate data, typified by Figure 9, show that at these very low, but finite flow rates ($Re \sim 1$), kinetic effects are still important, since the chamber volume influences the bubble volume. From the theory, this effect should be shown by a dependence on N_c, defined by Equation (17). Accordingly N_c values for the critical points, designated (a) in Figure 9, were calculated

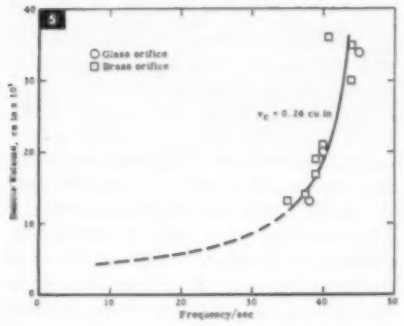
tip diam., in.	0.015	0.028	0.073	0.135
critical N_c	<0.99	0.852	0.837	>0.44

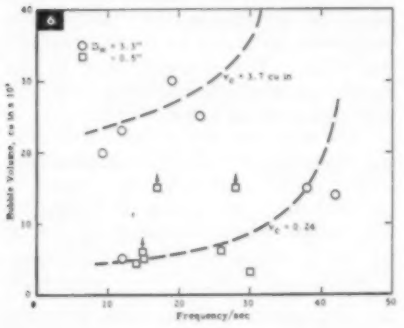
Apparently the critical corresponds closely to $N_c \sim 0.85$.

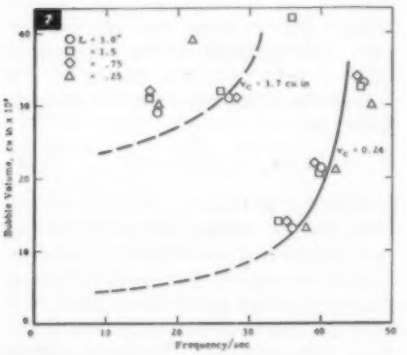
Visual observations showed that for small chamber volumes ($N_c < 0.85$) delayed release occurred; that is, the pendant bubble grew slowly and finally separated when its buoyancy became too large. This should correspond to the case of steady flow, and accordingly, ζ, Equation (13), should be small. On the other hand, the immediate release observed when $N_c > 0.85$ corresponds to a case where flow is abnormally large just prior to breakoff. In this case large values of ζ should occur.

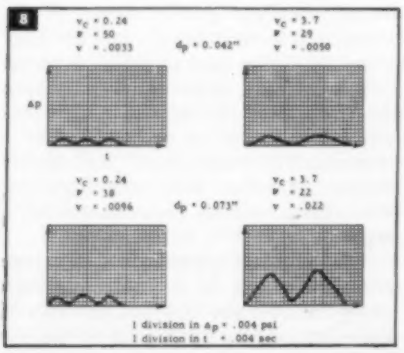
To check these observations and conclusions with Equation (13) or Figure 11, values of N_v and N_D must be known. Exact calculation requires knowledge of c_D and b, which are unknown. However, the correlations described below show that $c_D\,Re \sim 10^3$ to 10^4, and it is estimated that $b/\rho_L v \sim 10^{-2}$ to 1. Thus for $Re \sim 1$, $N_D < 0.03$. This also makes the L/c_D term in Equation (15) negligible, and since at these flows buoyancy is largely balanced by surface forces, $N_v >> 1$. In this region the trends shown in Figure 11 agree with the visual observations. The sharp decrease in ζ for $N_c < 0.85$ corresponds to the

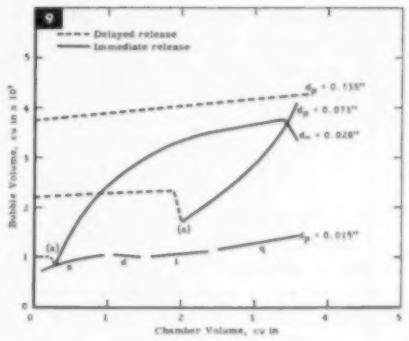


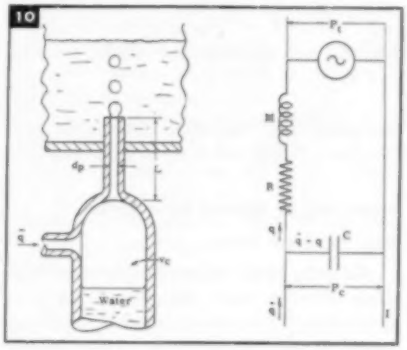


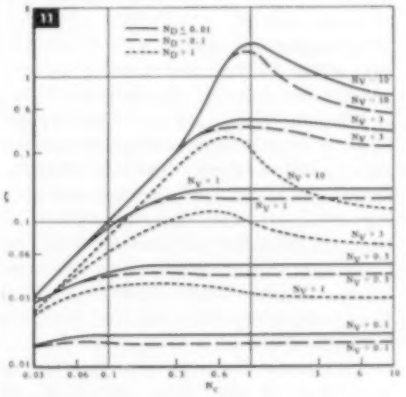


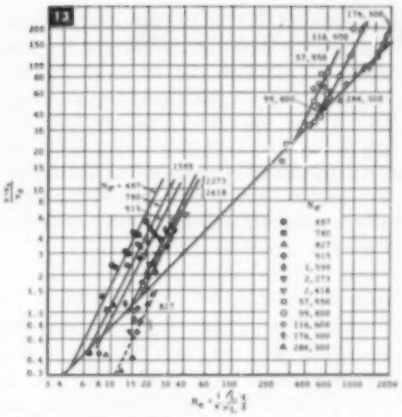


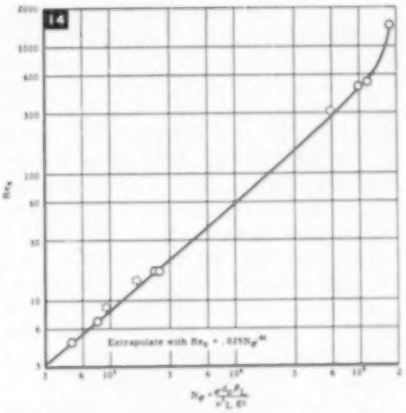












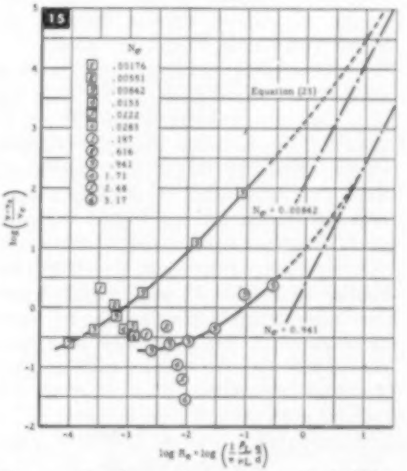


Fig. 4. Chamber volume effect. Air bubbles in water $d_o = 0.073$ in.

Fig. 5. Effect of orifice material. Air bubbles in water $d_o = 0.073$ in.

Fig. 6. Wall effect on bubble formation. Air bubbles in water $d_o = 0.073$ in.

Fig. 7. Effect of length of capillary. Air bubbles in water $d_o = 0.073$ in.

Fig. 8. Pressure fluctuations in gas train during bubble formation. Air bubbles in acetone.

Fig. 9. Slow bubble formation at treated orifices. Air bubbles in water.

Fig. 10. Typical gas train and its electrical analogue.

Fig. 11. Theoretical flow fluctuation function. Calculated from Equations (13) and (14).

Fig. 12. Formation of air bubbles in water.

Fig. 13. Bubble sizes in normal liquids at constant chamber pressure.

Fig. 14. Critical Reynolds numbers.

Fig. 15. Bubble sizes in viscous liquids at constant chamber pressure.

observation that bubble volume is nearly independent of chamber volume for low chamber volumes but is suddenly affected in the neighborhood of the critical. These curves do not explain the continued rise in bubble volume for increasing chamber volumes or the multiple bubble formation; however, these effects are not in disagreement with the theory.

PREDICTION OF V_o

From this analysis it is seen that the experimental bubble volume most nearly corresponding to v_o is the intercept at zero chamber volume. These values, for all the low flow rate data of this paper, are plotted in Figure 12 in the form suggested by Equation (18). It is apparent that for our data v_o/v_e is near unity and is a smooth function of d_c/d_p. Air-water data of other experimenters, which are included in this figure, show a more irregular relationship. This is probably due to the use of a constant, finite chamber volume in each study. Calculations show that for all of Smirnov and Polyuta's data and some of Guyer and Peterhan's data $N_G > 1$. It is easy to see from Figure 9 that data taken under such conditions might show an irregular dependence on tip size. The extent of the irregularity would, of course, depend on the tip length and bubble frequency used.

Unfortunately, the data of the present experiments were limited to a few tip sizes and to air-water alone. Thus, in spite of the possible chamber volume effects shown by Guyer and Peterhans' data, they were used to develop a general correlation for v_o. Figure 9 shows that deviations from the true values are not extreme. For each liquid a plot similar to Figure 12 was prepared and the best straight line located by least mean squares. The constants were then correlated with the density ratio to give the final equations

$$\frac{v_o}{v_e} = 0.068\left(\frac{\rho_L}{\rho_g}\right)^{1/6}\left(\frac{d_c}{d_p}\right)^m \qquad (19)$$

where

$$m = 0.16 - 0.11(\rho_L/1{,}000\ \rho_g) \qquad (20)$$

For the data of Guyer and Peterhans the standard percentage deviation of v_o from the predictions of these equations is 12.5% and that from their own nondimensionless equation is 20%.

Although Smirnov and Polyuta's data were not used in developing Equation (19), they were compared with it. The standard percentage deviation was 24.5% for all data and 19% for all but the ether data, which disagreed with the ether data of Guyer and Peterhans. With or without the ether data, the standard percentage deviation of

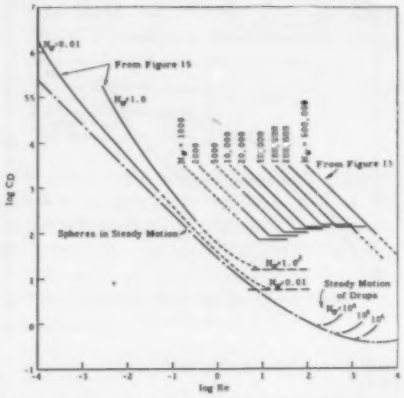


Fig. 16. Drag coefficients for bubble formation.

Smirnov and Polyuta's data from predictions of their own equation was 22%.

Formation at Normal Flow Rates

SELECTION OF DATA

At finite flow rates the chamber volume effect is still present. Thus it is desirable to select data for regions where small changes in N_c do not affect bubble size. The two cases which occur are of some interest.

In Figure 11 $\zeta \to 0$ as $N_c \to 0$. This is reasonable since a zero chamber volume would require steady flow into the forming bubble. This case is of interest because velocities and accelerations then depend only on shapes which can be estimated reasonably well, or observed photographically. Thus drag coefficients at breakoff could be calculated by applying Equation (6) to bubble size measurements. Unfortunately, Table 3 (A.D.I.) shows that very few data are available with $N_c << 1$.

An industrially more important case is that of $N_c >> 1$. This corresponds to constant chamber pressure. In most industrial applications of bubbling, many orifices are connected in parallel between a common chamber and a common liquid pool. Except in special, probably unstable, cases, the orifices are not in phase with each other. Thus, in effect, each orifice is supplied from an infinite chamber at constant pressure. Figure 11 shows that when $N_c >> 1$, ζ may still be large but is no longer a function of N_c. Moreover, with reasonable values of $c_D Re(> 2{,}000)$ and $b/\rho_L v(> 1)$, N_v and N_D are independent of L/d_p, unless it exceeds 100. Thus, in this region the fluctuating flow effects can be absorbed in an effective drag cofficient. From a study of the data, some experiments are found for which this drag coefficient can be determined. This shows that N_c is much greater than one for the data of Eversole, those of Guyer, and those of Benzing for the two smaller tips.

CORRELATION OF BUBBLE SIZE FOR $N_c >> 1$

If all effects of fluctuation and acceleration are absorbed in the drag coefficient, Equation (6) becomes at breakoff when $v_t = v_s + v$

$$g\Delta\rho v - [\pi g_c d_p \sigma - g\Delta\rho v_s - g_c(p_t - p_p)A_o] = c_D A_f \frac{\rho_L V'^2}{2} \qquad (21)$$

It seems reasonable to assume that the expression in brackets is independent of V'. Thus, by introducing the zero rate volume, v_o, and rearranging by the use of Equations (1), (3), and (4), one gets

$$\frac{v - v_o}{v_e} = \frac{c_D}{8}\frac{Re^2}{N_\sigma} \qquad (22)$$

If c_D is a function of R_e and N_σ alone, $(v - v_o)/v_e$, Re, and N_σ can be used as fundamental correlating variables. The resulting plot for the previously selected data of Eversole *et al.* and Benzing is shown in Figure 13. It is seen that ρ_L/ρ_g, μ_L/μ_g, and $N_{\sigma v}$ (which relates N_σ and d_c/d_p) apparently do not affect this correlation. The values of v_o used were calculated by Equations (19) and (20). The straight lines in the figure represent the following empirical correlation of the points:

$$5 < Re < Re_x \qquad \frac{v - v_o}{v_e} = .0760\ Re$$

$$Re_x < Re < 5\ Re_x \qquad \frac{v - v_o}{v_e} = \frac{.0760}{Re_x} Re^2 \qquad (23)$$

Re_x represents the transition Reynolds number. If these values are plotted against N_σ, the curve on Figure 14 results. Extrapolation at the high region of N_σ is very uncertain, but in the low region the following equation probably holds:

$$N_\sigma < 10^4 \qquad Re_x = .029\ N_\sigma^{0.82} \qquad (24)$$

The data of Guyer and Peterhans for olive oil and castor oil can be plotted in a similar manner. When this is done, Figure 15 results. The straight lines at the right-hand edge of this graph represent an extrapolation based on Equations (23) and (24). It is seen that the values obey the general trend of the values for normal liquids but are considerably higher than would be expected by extrapolation of the equations. Since drag expressed in terms of a drag coefficient or something proportional to it is expected to be abnormally high at low Reynolds number, it is not surprising that these values are considerably higher.

The physical significance of these correlations can be more readily seen when the lines are replotted in terms of the effective drag coefficient, by the use

of Equation (22). The result is given in Figure 16. The appearance of N_σ as a parameter is not surprising since the shape is important in determining the exact amount of drag. To provide a means of comparison, curves for spheres in steady motion and for drops in steady motion have also been presented. These are taken from Hughes and Gilliland (10). N_σ for this steady motion involves not d_p but d, the diameter of the drop itself. However, the way in which the increased distortion at high Reynolds number increases the drag is similar in the two cases. The fact that the drag coefficient is so much higher for the forming bubble is quite reasonable when it is remembered that this drag coefficient includes the effect of fluctuations and acceleration. The fluctuating flow produces abnormally high velocities just before breakoff and so the drag coefficient based on average velocity must be abnormally high. Also, the extremely high acceleration causes a high drag. This unusual drag during bubble formation may also partially explain the high mass transfer rates during bubble formation found experimentally in many cases.

EFFECT OF FLUCTUATING FLOW

The correlation of the remaining finite flow rate data is not yet complete. In general, a reduction in N_C at a given Re reduces $(v - v_0)/v_0$, often quite strongly. However, the extent of the reduction depends on the other parameters, the effect of which is not yet correlated.

Conclusions

From this study of the data of these experiments and of those obtained from the literature and from preliminary theoretical treament, the following conclusions can be drawn concerning bubble formation at simple orifices at rates which give uniform bubble size:

1. The chamber volume, v_c, has a strong effect on bubble size. This is especially marked when $v_c \simeq A_o \rho_g c^2/g\Delta\rho$. When v_c is much smaller, steady bubble growth occurs, and when v_c is much larger, constant chamber pressure occurs.
2. Data with nearly constant chamber pressure can be correlated in terms of an effective drag coefficient which depends on Re and N_σ alone and is many times larger than those for steady motion of spheres.
3. As long as tip length (or effective length equivalent to flow resistance) is less than 100 tip diam., it does not influence bubble size. This does not apply to experiments with thin orifice plates.
4. Because reasonable experimental dimensions often result in cases with v_c near its critical value, many experimental data on bubbling mechanics and mass transfer probably do not successfully model the industrial case of nearly constant chamber pressure.

Notation

A_f = frontal area of bubble, L^2
A_o = area of orifice $= \pi d_p^2/4$, L^2
b = carried mass, equivalent to accelerational drag, M
C = capacitance of chamber, Figure 10 and Equation (8), $L^4\theta^2/M$
c = velocity of sound in the gas, L/θ
c_D = drag coefficient, Equation (12)
d = diameter of a sphere of volume v, L
d_e = diameter of a sphere of volume v_e, L
d_p = tip diameter, L
g = acceleration of gravity, L/θ^2
g_c = conversion factor, $ML/F\theta^2$
K = pulsation parameter, Equation (14)
L = length of tip, L
M = inertance of tip, Figure 10 and Equation (10), M/L^4
Ma = mach number in tip, Equation (5)
m = density ratio function, Equation (20)
N_c = capacitance number, Equation (17)
N_D = drag effect number, Equation (10)
N_v = bubble volume number, Equation (15)
N_σ = surface tension number, Equation (4)
$N_{\sigma g}$ = surface tension-gravity number, footnote (d), Table 3
p_c = pressure in surge chamber, F/L^2
p_p = pressure in liquid at orifice level, F/L^2
p_t = pressure at the orifice, F/L^2
q = volumetric flow rate through one orifice, L^3/θ
q' = average value of q, L^3/θ
R = resistance of tip, Figure 10 and Equation (9), $M/\theta L^4$
Re = bubble Reynolds number, Equation (3)
Re_x = value of Re at intersection, Figure 13
t = time, θ
t_s = value of t just after breakoff, θ
V = mean velocity of bubble at any instant, L/θ
V' = value of V at breakoff for steady flow $= q'/\pi d^2$, L/θ
V_o = average velocity of gas through orifice, L/θ
v = volume of bubble formed, L^3
v_c = volume of chamber in gas train, L^3
v_e = volume of equilibrium bubble, Equation (2), L^3
v_o = volume of bubble formed at very low gas flow, L^3
v_s = value of v_t just after breakoff, L^3
v_t = volume of gas pendant from tip, L^3
$\Delta\rho$ = density difference $= (\rho_L - \rho_g)$, M/L^3
ζ = pulsation function, Equation (13)
μ_g = gas velocity, $M/L\theta$
μ_L = liquid viscosity, $M/L\theta$
ν = bubble frequency at orifice, q'/v, θ^{-1}
π = circumference/diameter
ρ_g = gas density, M/L^3
ρ_L = liquid density, M/L^3
σ = surface tension or interfacial tension, F/L

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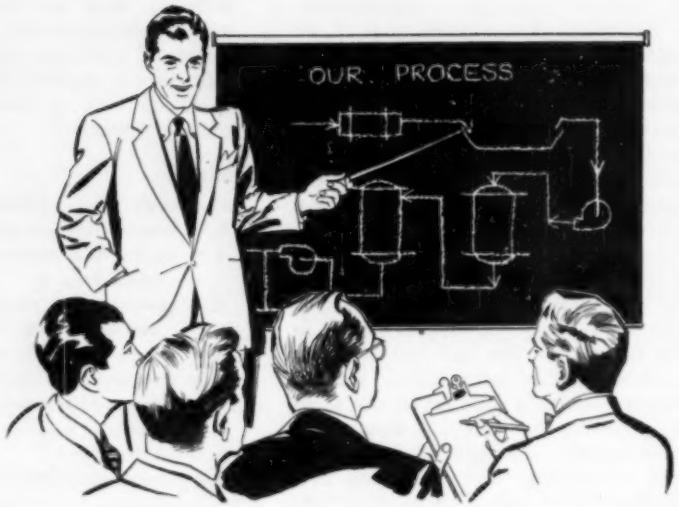
Presented at A.I.Ch.E. meeting, San Francisco, California.

INDUSTRY TEACHES THE TEACHERS



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Industry-sponsored schools for teachers have become a significant development in the chemical engineering teaching profession.

Basic idea of such schools is to have engineers in industry give the teacher added insight into the actual practices of their industries, and to provide some of the elusive information not in the standard literature. For the teacher such an experience is usually an inspiration for his professional work, and information for his students.

The plan, as originally conceived and promoted by the Chemical Engineering Education Projects Committee of the A.I.Ch.E., was first proposed by K. A. Kobe in an article appearing in Chemical Engineering Progress of September, 1951 (*1*). Since that time more than a dozen schools have operated successfully in the following way:

Arrangements are made with a company well known for its activities in a certain field of specialization to hold a one-day school for teachers at its own plant dealing with a well-defined subject in that field. Talks covering various phases of the subject are given by selected personnel of the company in morning and afternoon sessions. These talks are usually based on papers, preferably distributed in advance of the school meeting. An inspection trip of at least part of the company's facilities may be made to illustrate some of the material. The sponsoring company often provides a luncheon or dinner meeting to arrange an opportunity for individual discussions with the speakers and company officials.

All teachers located at schools within a reasonable traveling distance of the plant are notified and invited to attend. No fees are charged, the only expenses being those incurred by each individual for travel and perhaps a night's lodging. Only full-time teaching personnel holding the rank of instructor or above are eligible; this requirement eliminates graduate students or research associates who do no teaching. As the project is a regional activity, the enrollment is (desirably) kept small, averaging perhaps twenty students. Teachers serving as consultants for related or competing companies are of course ethically bound to state this fact clearly and not to attend the class unless the sponsoring company approves.

The chairman of arrangements is usually one of the teachers, self-appointed by virtue of having thought up the idea and of having discussed the possibilities with the company. The chemical engineering department of his university and/or the Projects Committee of the A.I.Ch.E. may act as cosponsors with the company. The very nominal miscellaneous expenses are usually borne by the company, with the university perhaps contributing mailing facilities, etc.

To the best of our knowledge, the accompanying list represents all such schools held since 1950. If other schools should be included, their omission is regretted and a word about them would be welcomed by the authors.

A group of teachers in Texas universities has made an annual event of their industry-sponsored school. They report that the event is now so well established and so eagerly anticipated each year, that some companies have inquired about the possible date of their participation. Other industry-sponsored schools have been scattered across the country. The idea seems to be spreading slowly; many hope it will gain momentum.

Chemistry teachers and those of other categories have been invited in some cases where the subject matter was of interest, particularly in regions where the low concentration of teachers of chemical engineering might otherwise have made a worth-while turnout impractical.

Every school so far has reported an enthusiastic response by the teachers attending. Companies have never refused to participate when properly approached, and some have given much thought to providing a pleasant as well as a profitable experience.

No one has a monopoly upon either the basic idea or the method of handling a school. Any teacher or company can start one. All that is required of the teacher is that he take it upon himself to be the "sparkplug" in his locality. Look around among the companies of your acquaintance. Select one which you, as a teacher, know would appeal to other teachers. Approach the proper official of the company with your sug-

gestion for a topic for the school. Tell him what has been done elsewhere. Point out that this is a simple way in which industry can make an effective contribution to education. These ideas are easy to sell. Arrange a tentative plan with the company, notify near-by teachers, and obtain an expression of their interest in attending. With these preliminaries established, you can proceed to work with the company in developing details of the program. If you need advice, suggestions, or moral support, the Projects Committee will be glad to assist.

While subject industry-sponsored schools have been largely initiated by teachers themselves, there are no reasons why industry shouldn't find it desirable to step up its pace of organizing such meetings. These are usually more elaborate affairs (lasting two or three days) initiated by the companies for somewhat broader objectives. Frequently the teachers and others from all over the country are brought to these meetings at company expense. The company, in addition to giving useful technical information to its guests, often is interested in acquainting them with its staff, facilities, and operations in order to establish a closer relationship with the universities from which it hopes to recruit future engineering employees.

One recent meeting of this kind may be mentioned as an example. On May 18-20, 1955, the Esso Standard Oil Company was host at the 1955 Esso Technology Conference at the Bayway refinery to a group of about thirty professors and editors of technical journals. This conference was described in C.E.P. (*2*).

Other related activities are the schools on instrumentation offered by the various instrument manufacturers, those offered by trade associations such as the Diesel Engine Manufacturers Association (DEMA), and the teaching methods seminar given by the General Electric Co.

Whenever professors are invited to participate in such groups, they are willing and anxious of course to attend. But rather than wait for industry to seek them out, they should take the initiative to organize industry-sponsored schools. The plan outlined above has proven workable. Opportunities to apply its techniques exist everywhere. It can be extended to parts of the country in which it has not been tried, and will become a regular part of the close cooperative relationship which should exist between industry and the engineering colleges.

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Industry-Sponsored Schools for Ch.E. Teachers Arranged in Conjunction with Chemical Engineering Education Projects Committee, A.I.Ch.E.

Date	Location	Company	Topic	Projects Committee Member
		1950		
May 20	Houston, Texas	Consolidated Chemical Industries, Inc.	Sulfuric acid industry	Kobe
		1951		
May 5	Houston, Texas	Engineers and Fabricators, Inc.	Heat exchanger fabrication	Kobe
November 9	Wilson Dam, Alabama	Tennessee Valley Authority	Ammonia technology	Anderson
		1952		
May 12	Everett, Massachusetts	Monsanto Chemical Company	Manufacture of sulfuric acid by contact process	Kranich
May 24	Baytown, Texas	Humble Oil & Refining Company	Distillation operations	Kobe
September 15	Emeryville, California	Shell Development Company	Fundaments of mass transfer apparatus	Stewart
November 21	Wilson Dam, Alabama	Tennessee Valley Authority & Girdler Corporation	Applications of catalysis in industry	Anderson
		1953		
May 1	Freeport, Texas	Dow Chemical Company	Evaporation	Kobe
November 7	Cincinnati, Ohio	Vulcan Copper and Supply Company	Process design of distillation units	Licht
November 13	Memphis, Tennessee	Humko Company & Buckeye Cotton Oil Company	Vegetable oil industry	Anderson
		1954		
May 14	Houston, Texas	Shell Oil Company	Design of modern crude distillation unit	Kobe
		1955		
May 20	Sabine River, Texas	Du Pont	High pressure synthesis of methanol	Kobe
October 15	S. Charleston, West Virginia	Carbide & Carbon Chemicals Company	Heat transfer	Koehler
December 9	Wilson Dam, Alabama	Reynolds Metals	The aluminum industry	Anderson

PILOT PLANT FOR separation of reactor fuel elements

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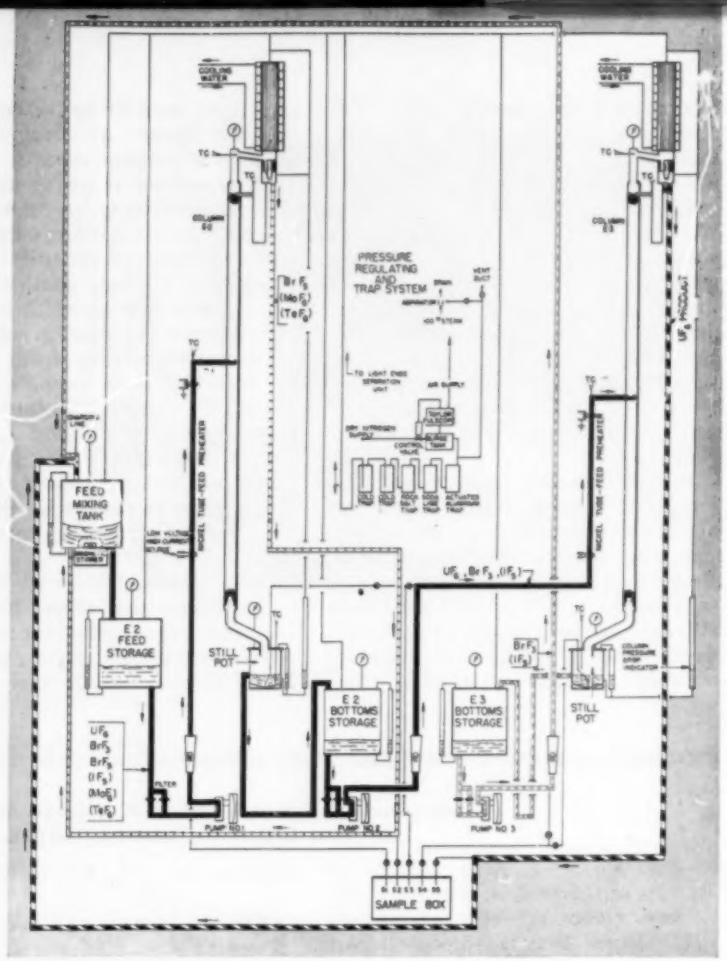

Fig. 2. Diagram of continuous process light-ends separation unit.

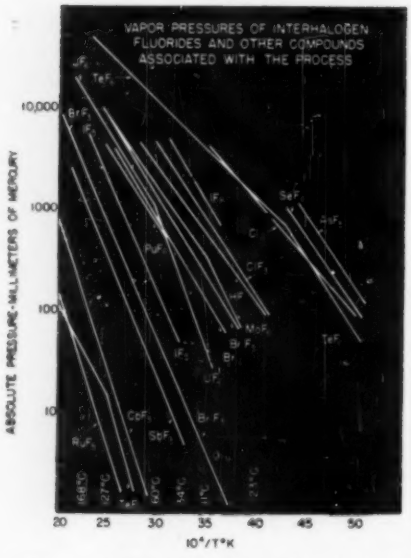

Fig. 1. Vapor pressures of interhalogen fluorides and other compounds associated with the process.

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The requirements for multicycle reprocessing of partially burned fuel from heterogeneous nuclear reactors are (1) high fuel yields and (2) low-cost per cycle. Distillation as a means of separating the fuel from the fission products presents an intriguing possibility for realizing these requirements.

In April, 1949, Sheft, Andrews, and Katz (*1*) of Argonne National Laboratory suggested using the interhalogens in liquid-phase fluorination of pile-irradiated uranium. Processes based on this suggestion have been developed at Argonne and at Oak Ridge National Laboratory by the use of BrF_3 and ClF_3 respectively as fluorinating agents. The processes involve the dissolution of the uranium and consequent separation by distillation of the various fluorides, including the fission-product fluorides and plutonium fluoride, to obtain a pure uranium hexafluoride product.

This separation method with its UF_6 end product would have a distinct advantage where the recovered uranium is to go to a diffusion plant for enrichment. While not important in reprocessing highly enriched fuels, the possibility of separating plutonium as PuF_6 from irradiated natural uranium lends further impetus to work on this process.

The investigation described in this article was undertaken in cooperation with the Argonne National Laboratory and is concerned with the pilot-plant-scale separation of the light- and fission-product fluorides and bromine-fluorine compounds from uranium hexafluoride by distillation. A more complete description of this investigation has been presented in a Brookhaven National Laboratory report (*2*).

MATERIALS TO BE SEPARATED

The approximate vapor pressures of the important fission-product fluorides are indicated in Figure 1, a plot of vapor pressure as a function of the reciprocal of absolute temperature. It will be noted that the only fission-product fluorides which are more volatile than the BrF_3 dissolver solution are IF_5, MoF_6, TeF_6, SeF_6, and AsF_5. Of these only MoF_6, TeF_6, SeF_6, and AsF_5 are more volatile than UF_6. SeF_6 and AsF_5 are low-yield materials and not present in significant amounts. MoF_6, because of the short half life of the Mo, is no longer an active contaminant after cooling times of the order of ninety days. The rare

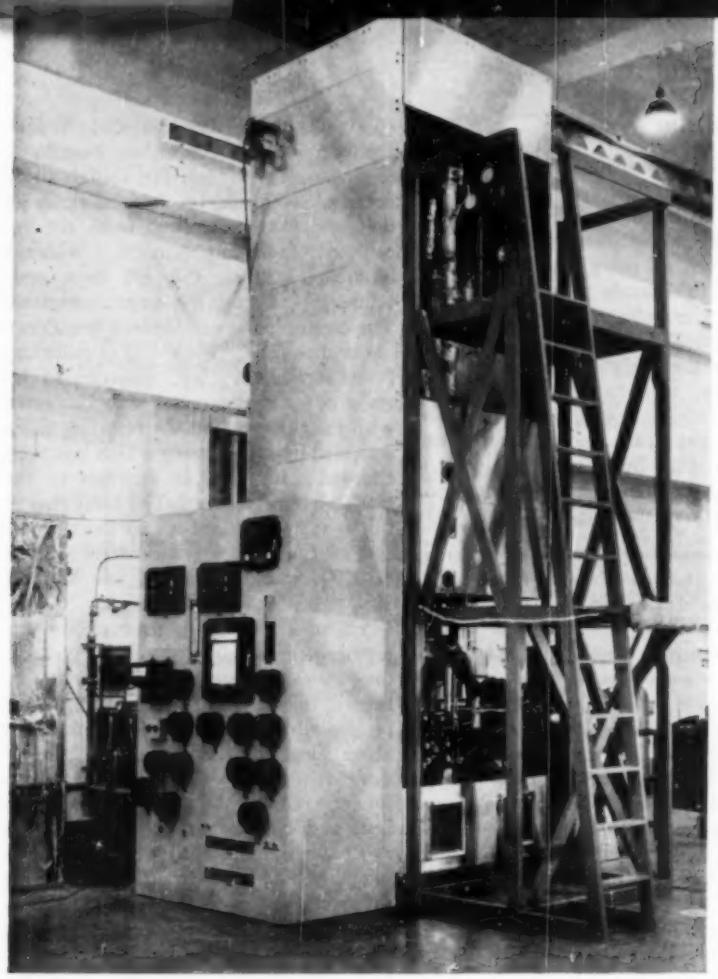

Fig. 3. Light-ends separation unit showing control board and box enclosure.

gas fission products, of course, also would be contained in any cut taken above UF_6 in volatility. None of the other fission-product fluorides are sufficiently volatile to be removed in any significant amount when BrF_3 is boiled away from the dissolver container residue. Argonne (*3*) has shown that with proper control of the dissolving operation the plutonium can be kept behind as PuF_3 is the dissolver residue.

The fission products of importance, then, from the distillation standpoint, are the thirty-two-day Te^{129}, presumably occurring as TeF_6 and eight-day iodine, presumably as IF_5.

SMALL SCALE NOT CORRELATIVE

Small-scale distillation experiments at Argonne showed that the tellurium activity was somewhat harder to separate from the UF_6 than would have been predicted on the basis of its vapor pressure. This led to the speculation that a compound such as Te_2F_{10} might be forming, or that under conditions where BrF_3, Br_2, and BrF_5 were present there might exist some complex compound formation between tellurium, fluorine, and bromine that reduced the effect of volatility. There were also some grounds for suspecting that the small size of the distillation apparatus even though theoretically adequate for the separation, might limit the amount of UF_6-Te separation obtainable because of a large top sample to column holdup ratio or some other feature of the design.

The Pilot Plant

Argonne and Brookhaven personnel as A.E.C. contractors jointly decided to build a pilot-plant scale distillation unit at Brookhaven to study the separation of tellurium activity from UF_6. The unit was also to provide engineering information on column pressure drop, height of equivalent theoretical plate, and other factors that would be of use in the design of a large-scale pilot plant capable of handling activity of Hanford level, including the slug dissolving operation to be built at Argonne. Because it was felt that the eventual process would be continuous, it was decided to study the light-end distillation separation with tracer amounts of activity as a continuous process with recycling of the column overhead and bottoms streams.

In the eventual processing the first distillation will probably be a batch separation of light-end fission-product fluorides, BrF_5, UF_6, and a portion of the BrF_3 from the dissolver. This fraction will serve as feed for the continuous distillation unit. The amount of BrF_5 that will be present is still an undetermined factor.

In dissolvings performed at Argonne (*3*) with F_2 to regenerate BrF_3, the solution at the end of the run has contained about 10 mole % BrF_5, 10 mole % UF_6, and the remainder BrF_3. If such a mixture were used as a feed to the first column in the continuous process, one would have the option of operating this column at atmospheric pressure since the concentration of UF_6 anywhere in the column could be kept below the freezing concentration. The major portion of the light end activity could then be removed in the overhead BrF_5 stream from an unpressurized column. The bottoms containing the UF_6, BrF_3, and the small amount of iodine activity would, however, have to be fractionated in the second column at about 2 atm. total pressure because of the triple point of UF_6 at 1½ atm.

THE BROOKHAVEN PILOT UNIT

The flow sheet for the light-end separation unit at Brookhaven is shown in Figure 2.

The unit consisted of two distillation columns of similar size and construction connected with storage tanks, pumps, and other auxiliaries in such a manner that a synthetic mixture of UF_6, BrF_5 (with or without BrF_3 present), and light-end fission-product activity could be pumped to the first column where the UF_6 could be stripped of the more volatile components. The column bottoms, consisting of the UF_6, BrF_5, and such other fission components not removed as overhead, could then be pumped as feed to the second column where the UF_6 product was taken off as overhead and the BrF_5 removed as bottoms for recirculation. Figure 3 is a photograph showing the control panel and box enclosure.

The various system components will be described briefly.

Fabricated from standard 2-in. aluminum pipes, the columns were 9 ft. high and were packed with 5/32-in. I.D. aluminum single turn helices made from #24 B&S gauge (0.0201 in.) 2S alloy wire. The pumps were 3-gal./hr. Lapp Insulator Company, Inc. Pulsafeeder units with double-diaphragm-hydraulic pulse transmitting systems. The primary diaphragms were located outside the temperature-controlled box which housed the pilot plant and the pulses were transmitted by means of The M. W. Kellogg Company's Kel-F oil to the secondary diaphragms inside the box. These diaphragms actuated check valve systems in the process streams. The flows were metered by means of rotameters which were calibrated by measuring liquid-level changes in the storage tanks.

The storage tanks into which the various overhead and bottom streams returned were equipped with a magnetic stirring device to insure adequate mixing before the liquid was passed to the feed-

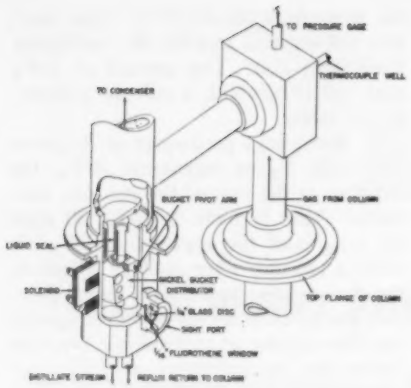

Fig. 4. Liquid distributor head.

storage tank. The liquid levels in the storage tanks and still pots were measured with Fluorothene sight glasses which were equipped with suitable valving so that they could be isolated from the system when measurements were not taken. The condensers were cooled with temperature-controlled water. They were equipped with liquid-dividing heads which were specially constructed so that the gas flowed up from the column by a separate path and the condensed liquid flowed down through a gas seal to a solenoid-actuated nickel bucket which distributed the condensate between distillate and reflux streams as shown in Figure 4.

The pressure on the system was regulated by means of an air-actuated diaphragm valve and Taylor Instrument Co. Fulscope combination. A small bleed of nitrogen was maintained through the regulating valve, the downstream side of which was connected to both a vent line and a trap system. The opposite end of the trap system was connected to the gas phase of the pilot plant. The regulating system operates in such a manner that, to reach the equilibrium pressure setting on the Fulscope control, gas could flow in one direction or the other through the cold and chemical traps.

A liquid-sampling technique was worked out whereby the liquid stream to be sampled flowed through a tee as near as possible to a tandem-valve combination below which the sample was taken. After purging the valve line, the sample was drawn off into a ½-in. diam. 5-in. long aluminum tube where it was frozen. The tube was then capped with ½-in. standard Parker Company flare fittings.

The 2S and 3S aluminum alloys were used for construction of most of the equipment. All liquid and gas lines were 2S and 3S ¼-in. aluminum tubing with the exception of the A nickel feed preheaters and the ¼-in. copper gas transfer lines to the trap system. The Parker Company's 17 ST, 24 ST, and 14 ST aluminum flare fittings were used in connecting the tubing to the various components of the system.

All pump parts in contact with the process fluids were either Monel or Teflon. Flanges were fitted with Teflon gaskets where flanging was convenient for disassembling. Other flanges and tube leads to and from vessels were heliarc-welded.

Data and Results

Runs made with this system have been based on the following objectives: to determine with tracer amounts of light ends whether or not there would be any activity, such as tellurium, that would be difficult to separate from the UF_6, to determine the column height requirement for the UF_6-BrF_3 separation, to sharpen up the analytical techniques for determining small amounts of BrF_5, UF_6, and BrF_3, and to obtain values for column-height requirements for the separation of the BrF_5 from the UF_6.

Information of the operation has been obtained in five stages as follows:

Stage 1: measurement of height equivalent to a theoretical plate for a mixture of *n*-heptane and methylcyclohexane at total reflux in first column.

Stage 2: operation with a mixture of BrF_3 and BrF_5 to check out pumps, to measure packing pressure drops as a function of boil-up rate, and to check on operability of other components of system.

Stage 3: operation with a mixture of BrF_3, BrF_5, UF_6, and tracer amounts of selenium activity to measure distribution of UF_6 and selenium fluoride between bottoms and overhead as a function of feed rate, boil-up rate, and reflux ratio.

Stage 4: operation with BrF_3, UF_6, and tracer amounts of all light-end activity from a solution of irradiated UF_4 in BrF_3.

Stage 5: investigation of tellurium complex formation.

Stage 1. Results of the H.E.T.P. were in good agreement with those of Fenske, Lawrowski, and Tongberg (*4*) for a similar size column and packing by the use of mixtures of *n*-heptane and methylcyclohexane.

Stage 2. System components testing. After thorough removal of the mixture of organics from the first column, the evacuated system was fluorinated by introducing ClF_3 gas to a pressure of about 20 lb./sq.in. After a 24-hr. interval, the gas was pumped off and the system pressurized with prepurified nitrogen. A mixture of about 80 mole % BrF_3 and 20 mole % BrF_5 was transferred to the system and pumped through it. The mixture used was obtained from the Harshaw Chemical Company as Technical Grade BrF_3. Construction of the pumps had to be modified to obtain satisfactory operation. At this stage also the column pressure drop as a function of boil-up rate for BrF_3 at atmospheric pressure was measured.

Stage 3. Operation with a mixture of BrF_3, BrF_5, UF_6, and tracer amounts of selenium activity.

The system was tested next to determine the amount of decontamination obtainable with the light-end fission-product fluorides. Selenium hexafluoride was selected for the initial study because Se^{75} could be obtained easily as the sole gamma emitter from the irradiated selenium metal, whereas irradiated tellurium would have contained I^{131} to mask the decontamination. The boiling point of selenium hexafluoride is about 7° C. below that of tellurium hexafluoride. A 10-g. quantity of irradiated selenium metal was contacted with fluoride gas and the resulting SeF_6 was bled into the system which had been charged with UF_6 in addition to the BrF_3 already present. The total charge in the system was about 60 lb., and the composition was approximately 4 mole % UF_6, 15 mole % BrF_5 and 81 mole % BrF_3.

The operation of the first column was tested with this synthetic feed, the bottoms and column overhead being returned to the feed make-up tank for recirculation. The feed was introduced at an elevation 5 ft. from the base of the 9-ft. column. Conditions of operation and data on the three runs on which feed and bottoms analyses were made are shown in Table 1. In these runs difficulty was experienced in obtaining satisfactory top samples because of a local cool section of the box in the region of the tops-sampling valves. The tops compositions have been estimated from heat and material balances. The relative amounts of selenium activity in feed and still pot were measured both by radiochemical analysis and total gamma count corrected for uranium activity.

It will be noted that in runs 30 and 31, the distribution of selenium activity between bottoms and overhead is close to what would be expected on the basis of both the UF_6 distribution and the relative volatility of 15 to 20 between the two components. In run 33, however, only about one tenth as much selenium in the bottoms would be expected in view of the fact that most of the UF_6 was in the overhead stream. Additional runs under similar conditions substantiated the existence of a stronger association between BrF_3 and the fluoride of selenium than was anticipated on the basis of vapor pressure information for the two components individually.

This close association was found later with tellurium also and is evidently attributable to the formation of both a highly volatile compound and a nonvolatile compound with both tellurium and selenium in the presence of BrF_3.

The accuracy of the bromine and uranium analysis for the samples of these runs was not sufficient to allow any interpretation on the efficiency of

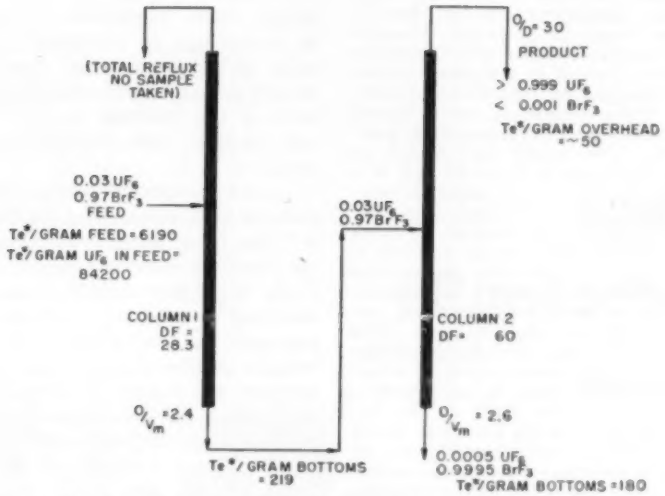

Fig. 5. Flow sheet of run X-Y made with tracer amounts of fission-product activity.

Table 1.—Selenium Decontamination Runs

run number	stream compositions: feed UF_6	feed BrF_3	feed BrF_5	bottoms UF_6	bottoms BrF_3	overhead (estimated) UF_6	overhead (estimated) BrF_5
30	4.40	18.5	77.1	2.66	97.3	11.1	88.9
31	2.30	10.4	87.6	1.04	99.0	10.5	89.5
33	1.64	15.0	83.4	0.09	99.9	2.5	97.5

run number	feed rate (gal./hr. @ 78° C.)	feed temp. (° C.)	O/D	O/V_m	selenium activity distribution activity/gram feed / activity/gram bottoms
30	3.00	78	0.73	3.3	15.0
31	3.00	78	1.00	3.7	15.5
33	1.83	115	3.2	2.6	28.2

run number	column pressure top (mm.abs.)	column pressure bottom (mm.abs.)	column head temp. (° C.)	column still temp. (° C.)	column still heat input (B.t.u./hr.)
30	2390	2440	79	158	2580
31	2250	2300	81	149	2580
33	2130	2170	77	155	2580

Table 2.—Tellurium Decontamination

sample	column	tellurium activity/g. of sample	tellurium activity/g. tops / tellurium activity/g. bottoms
1st still pot	1	63	38.4
2nd still pot	1	59	26.6
3rd still pot	1	75	20.0
1st tops	1	2420	38.4
2nd tops	1	1570	26.6
3rd tops	1	1500	20.0
1st still pot	2	50	9.5
2nd still pot	2	52	8.9
1st tops	2	475	9.5
2nd tops	2	463	8.9

the BrF_5-UF_6 separation. The possibility of a maximum relative error of 6% exists for the BrF_5 at the concentrations in which it was present in the feed and bottoms.

Stage 4. Runs with all light-end activity in system. In order to test the system with fission-product light-end activity, a synthetic feed was made up which consisted of about 3 mole % UF_6 and 97 mole % BrF_3 to which was added the volatile fluorides from 45 g. irradiated UF_4. The UF_4 had received an irradiation of about 4×10^{18} neutrons/sq.cm. (three and one-half weeks in the Brookhaven reactor) and had cooled for thirty days at the time of processing. The UF_4 was fluorinated with a mixture of 100 cc. of BrF_3 and 20 cc. of BrF_5; the latter was added to react with the bromine formed to regenerate BrF_3.

This feed was pumped to the first column at a rate of 1.74 gal./hr. The column head was operated at total reflux and the heat to the feed and still pot was such that the feed was close to its boiling point and the still pot boil-up rate was 90.3 g. mole/hr. based on BrF_3. Under these conditions 3.5% of the tellurium activity entering with the feed left with the mixture of UF_6 and BrF_3 overflowing from the still pot. This bottoms mixture was fed then at a rate of 1.39 gal./hr. to the second column where the UF_6 was separated from the BrF_3. The second column was operated with a reflux ratio of 30 to 1, with the feed as liquid at the vaporization temperature and with a still-pot boil-up rate of 57.7 g. mole/hr. of BrF_3. Analysis for tellurium activity/g. of UF_6 in the UF_6 product, in the feed, and in the still pot from samples taken during the run showed that the product UF_6 contained 1/60 of the activity of the feed to the second column. The tellurium activity per gram of still-pot solution was only slightly less than that found per gram of feed, indicating, as with the selenium activity previously used, a closer association of the tellurium with the BrF_3 than would have been expected. Figure 5 shows the pertinent features of the run.

The over-all decontamination factor for tellurium for the two columns was thus about 1,700. Since neither iodine nor molybdenum activity was found in the product UF_6, the gross gamma decontamination factor for the runs was estimated to be about 10^6 and the gross beta decontamination factor about 2×10^5 based on the activity of the original 45 g. UF_4. Analysis for bromine in the UF_6 product showed no detectable

halide; analysis would have detected about 1 part in 1,000 bromine in the UF_6. The still-pot solution contained 0.0005 mole fraction UF_6 in BrF_3.

On the basis of these analyses, the number of plates in the second column was calculated to be a minimum of eighteen, based on the Raoult's law assumption and the respective vapor pressures. The H.E.T.P. for the 9 ft. of 2-in. column packed with 5/32-in. helices thus was estimated to be less than 6.3 in. Calculations of a similar nature on other runs have shown H.E.T.P. values of between 4.5 and 6.0 in., roughly twice the values obtained when the column was originally tested with *n*-heptane and methylcyclohexane.

Stage 5. Investigation of tellurium complex formation. Several experiments were conducted to check the evidence of a tellurium and selenium complex formation which had been obtained in the operations described in stages 3 and 4. In the first experiment, both columns were operated at total reflux for 6 hr. Samples of tops and still pot were then taken and analyzed for tellurium activity. The columns contained a mixture of BrF_3, UF_6, and BrF_5 with the interface between UF_6 and BrF_3 at about 3 ft. from the top of the column.

Data for the several samples taken are shown in Table 2. In order to obtain the results for column 1 that are shown in this table, if one makes the assumption that all the tellurium was present as TeF_6, the average relative volatility between the TeF_6 and the other components of the system would have to have been less than 1.3, on the basis of these data, and assuming the 18-plate column demonstrated in stage 4.

It is apparent from these results that the tellurium in the still pot was in some other form than TeF_6. The significance of the lower tops to bottoms tellurium-activity ratios for column 2 was blurred by the fact that some amount of material had been pumped through the entire system in the time interval since the run of stage 4. Because of the similarity between the two columns, the lower activity ratio for column 2 at total reflux did, however, indicate the presence of a higher percentage of the complexed for lower fluoride tellurium.

In order to verify the presence of a nonvolatile tellurium compound, one of the still-pot samples taken on column 1 at total reflux was placed in a fluorinated container similar to the hydrolysis bomb and vacuum distilled until about ⅓ of the total BrF_3 was taken over into a cold trap. A tellurium analysis on the remaining BrF_3 showed that the specific activity had increased proportionally while no activity could be detected in the BrF_3 of the cold trap.

The next test was designed to illustrate the complex or lower fluoride formation from the volatile tellurium fluoride compounds. Gas phase fluorides of tellurium formed in a manner similar to that described by Junkins and Barber (*5*) for TeF_6 formation, were passed into a vessel containing about 40 g. purified BrF_3. The vessel was cooled so that the TeF_6 and BrF_3 could mix in a liquid phase and the two materials were allowed to interact overnight. The solution was then vacuum distilled. A check on the activity level at the outside of the container as a function of container pressure showed a straight-line relationship with essentially background activity at 29 in. Hg vacuum. The remaining BrF_3 was analyzed for tellurium activity. A concentration of tellurium of the same order of magnitude as that found with the BrF_3 of the still pots of the total reflux runs was found. Further vacuum distillation did not decrease this concentration. It was evident that a relatively nonvolatile tellurium compound had been formed. The containers used for this test for generating the volatile tellurium fluorides and for interacting these with BrF_3 were the same type as the hydrolyzing bomb. All excess fluorine had been removed from the TeF_6 by freezing the TeF_6 generating vessel and pumping off before the gaseous tellurium was transferred to the vessel containing the BrF_3.

The formation of a nonvolatile tellurium fluoride was checked in still another manner as follows: about 10 g. of pure BrF_3 were placed in a fluorinated aluminum sample tube. The tube was capped and the BrF_3 frozen. About 30 mg. of tellurium metal powder (the same material that had been used in the test described above) which had been irradiated for three months and cooled for six months was placed in the tube above the frozen BrF_3 and the tube again capped. The gamma activity of the tellurium was measured at the outside of the tube. After the tellurium had dissolved, the cap was removed and the space above the liquid BrF_3 was purged with prepurified nitrogen. That no decrease in activity was detectable at the outside of the tube showed that a negligible amount of the tellurium was in the gas phase. There was no evidence of any undissolved particles in the BrF_3 solution. The tube was then heated to drive off any volatiles including the BrF_3. With the last traces of BrF_3 out of the tube, no change in the activity level occurred. A small amount of what appeared to be a brownish, waxlike material could be seen at the base of the tube. On further heating, this material gave off a small amount of white fumes. The tube was then cut in two, close to its inside bottom and the activity metered in the two parts. Most of the activity was at the very bottom of the tube, and at the temperatures which had existed when the fumes had been given off, the remainder of the material had evidently fused with the aluminum.

The same procedure was carried out with BrF_5 in place of the BrF_3 and similar results were obtained. The data seem to justify the assumption that a fairly nonvolatile form of tellurium can be formed under certain conditions of dissolving tellurium in either BrF_3 or BrF_5. Whether this tellurium exists as TeF_4, as $(BrF_2^+)_2(TeF_6^=)$, or in some other form has yet to be determined. There is evidence in the data on dissolvings of irradiated uranium made at Argonne that some small amount probably in the neighborhood of 0.6% of the tellurium remains behind with the BrF_3 when the UF_6 is distilled away.

Several samples of column overhead material were subjected to the following test after being stored in the sealed sample tubes for one- and two-month periods. A weighed amount of each of the overhead samples was hydrolyzed and analyzed for tellurium. A second weighed portion of each of the overhead samples was boiled to dryness, fresh BrF_3 added, and the mixture hydrolyzed. Between 3 and 45% of the tellurium was found to be in a nonvolatile form after these periods, the sample which had been stored longest having the highest percentage of nonvolatile tellurium. Such a conversion may have application in the purification of any unsatisfactorily decontaminated batches of UF_6.

The primary concern in processing considerations is the rate at which the nonvolatile tellurium fluoride is converted to the volatile or if it is converted at all. Evidence obtained in stage 4 and from the above tests indicates that the nonvolatile tellurium once converted to this form is stable. Still to be investigated in more detail is the mechanism by which the volatile-tellurium fluorides are converted to the nonvolatile. Granted the stability of the nonvolatile form, the only concern here would be the formation of an intermediate volatility compound such as Te_2F_{10} as one step in the process of conversion. Any amount of Te_2F_{10} carried over into the second column would contaminate the UF_6 if provision were not made to allow the conversion to be completed before feeding to the second column.

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Presented at A.I.Ch.E. meeting, Cleveland, Ohio.

Lamp Equipment for Photochemical Processes

EMPLOYS HIGH INTENSITY MERCURY VAPOR ARC

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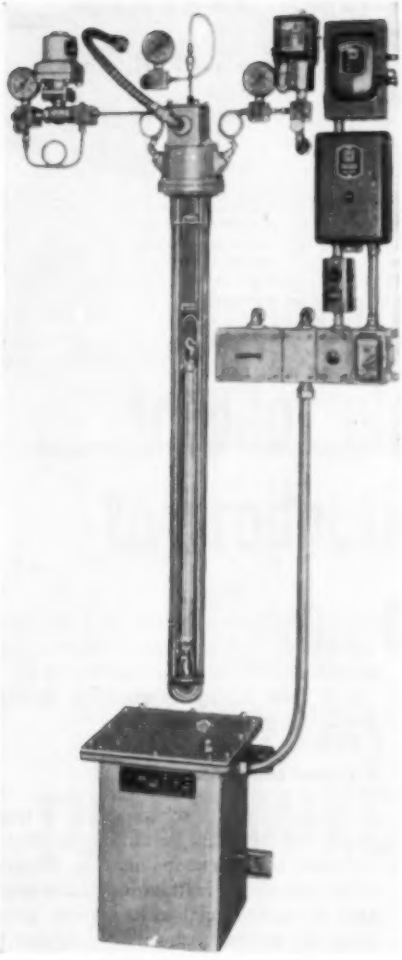

Fig. 1. Automatic photochemical equipment.

The high intensity mercury vapor arc lamps which have been developed by lamp engineers during the past few years are efficient producers of radiations suitable for the promotion of many photochemical processes. The application of these lamps does introduce, however, some problems that have been discussed previously (*1*).

When lamps are employed in the photosensitization in chlorinations, experience has indicated the desirability of equipment designed expressly for the application. Accordingly a development was begun in 1947 which has culminated in the use of equipment that will provide automatic control in lamp operation of those factors which have featured prominently in the creation of problems. Some such equipment has been made available to chemical manufacturers who have used it commercially under actual service conditions and have found its performance to be satisfactory on the average.

This paper describes briefly the essentials of this equipment.

Description of Equipment

Figure 1 illustrates a single-unit assembly for a 4,250 w. high intensity mercury vapor arc. The lamp is mounted within a glass immersion well provided with controlled water and nitrogen gas flow for temperature regulation. The controls are electrically interlocked with the electric supply to the lamp. In addition to an electric control for the lamp itself, the electric components comprise pressure switches and solenoid valves to extinguish the lamp promptly if glass parts or lamp failure occurs, whereby the possibility of explosion is averted. All electrical equipment is constructed moisture-proof and vapor-free.

GLASS IMMERSION WELLS

The immersion-wells assembly consists of two glass wells telescoped one within the other. The wells are provided with heavy glass flanges which are secured and sealed into a corrosion resistant aluminum header. The outer well is flanged with heavy glass for a length of 5 in. below the header to allow for the mounting of the assembly into the usual chemical reaction tank. This assembly arrangement was adopted after considerable experimentation because it appears to provide the best facility for maintenance.

In some of the earlier stages of the development, Pyrex was used for the immersion wells. It was soon disclosed that Pyrex was not satisfactory because it undergoes rapid decrease in transparency to the photochemical radiations when exposed to the intense radiations produced by these lamps. The transmission of solarized Pyrex for ultraviolet and blue light is much less than that of new Pyrex glass.

Fortunately a satisfactory solution was available in Corex (D) glass (Corning Glass Works). This glass not only transmits ultraviolet better than Pyrex when new, but it is also little affected by exposure to intense radiations.

COOLING SYSTEM

High-wattage lamps produce considerable heat. Excessive heat may cause the formation of carbonization deposits upon the outer surface of the immersion well, or surface flash on the inner surface of the inner well which contains the mercury lamp. If either of these formations should occur, a decrease in transfer of radiant energy from the lamp to the reaction medium results.

It is necessary to prevent this loss in radiant energy. This can be done by the employment of a cooling medium. In this equipment filtered water at a temperature not exceeding 150° F. is circulated in the space between the inner and the outer wells assembly at a rate of 1 to 2 gal./min. with a pressure of 35 lb./sq.in.

If iron oxide deposits from the water on the glass walls of the light jacket, this condition can be stopped entirely by the installation of a completely plastic closed-circuit water-piping system.

The water system is safeguarded against failure in the water supply by the inclusion in the equipment of automatic pressure switches and electric circuit-breakers arranged to extinguish the lamp if and when loss of pressure occurs in the cooling system. The lamp installation ceases to function until correct water pressure again is restored.

The pressure switches must be installed where they are not subject to corrosive fumes. They become sluggish easily and fail to act properly. Accordingly a system and schedule should be set up for frequent testing under operating conditions.

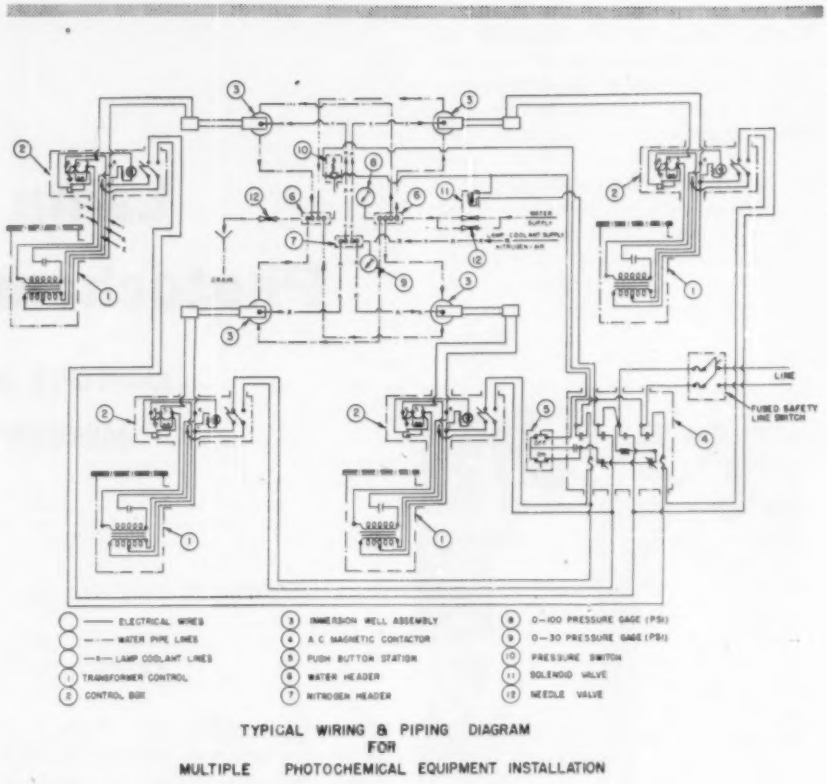

Fig. 2. Typical wiring and piping diagram for multiple photochemical equipment installation.

Protection from Vapor Explosion

The external components of the mercury lamp during operation attain temperatures in the order of 1,000° F. These temperatures can promote the ignition of explosive vapors such as are frequently present in the processing room. In order to prevent vapor explosion by thermal reaction or by electric sparks, the inner well which contains the mercury lamp is maintained at a positive pressure of 20 to 25 lb./sq.in. nitrogen gas. This provides a positive pressure to prevent seepage of explosive vapors into the well. It provides also a neutral atmosphere for the external metallic parts of the lamp, and contributes, therefore, to the useful life of the lamp.

Control for Constant Electric Power to Lamp

The reaction velocities of some photochemical processes are directly proportional to the intensity of the photosensitizing light. It is desirable to avoid abrupt changes in light output such as may occur when electric supply voltages fluctuate. Such fluctuations if frequent or drastic may affect the economics of a process. This difficulty was overcome by the development for this equipment of voltage-regulated constant wattage lamp controls comprising reactive and capacitive electrical components which are power-factor corrected to about 90%. This type of control automatically maintains the wattage of the lamp within narrow limits of a few per cent for large variations in the supply voltage, and regulates perfectly for all minor changes in voltage.

The controls are enclosed in oil-filled enclosures, which are moisture-proof and vapor-free. They are durable, long-service equipment. Electrically the controls may be installed as individual units or interconnected in any number for control by master switching or supervisory services.

Corrosion Protection

Protection of the metallic parts of the equipment from attack by acids and vapors has been achieved by a generous application of silicones, which have proved durable and satisfactory in service. Tygon tubing is used for flexible water and gas connections.

A Typical Installation

Figure 2 shows schematically a typical four-lamp multiple automatic photochemical equipment installation. Several of these multiple installations have operated in commercial chlorination processes for several years. They appear to be performing the functions for which they were designed by engineers. Their employment has reduced hazards to plant personnel and damage to equipment. They have reduced production losses, reduced maintenance and lamp replacements, and appear to insure an economical utilization of the radiations. Lamps are operating under conditions which are favorable for slow deterioration in radiation output.

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Turbo-Topics

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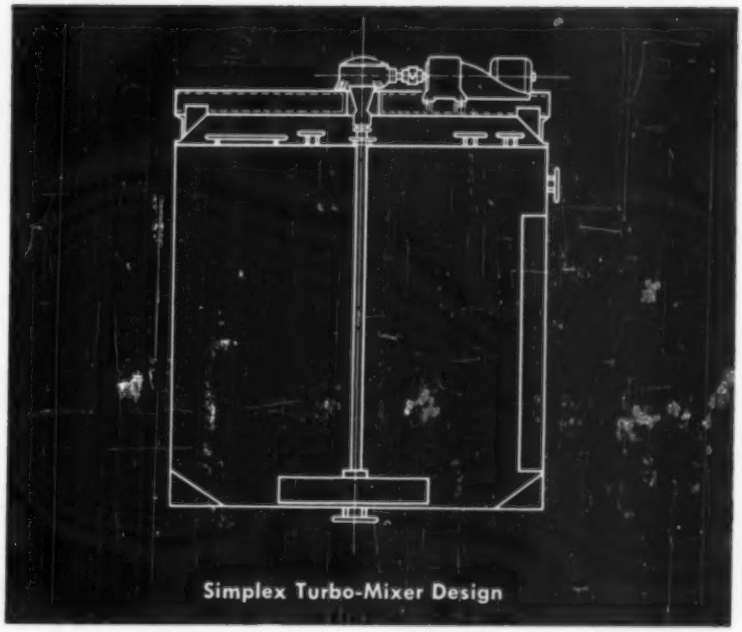

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HIGHLIGHTS of chemical engineers' 48th annual meeting

Chemical industry on brink of new movement to standardize the mechanical components of its plants (Brand, Monsanto) . . . Carbide's Ullock, leader in "how to evaluate pump design" activity, told how to make your own shaft deflection measurements (see it soon in *C.E.P.*) . . . Murdock (Allis-Chalmers), speaking for pump industry, estimated conversion to standard designs might cost average manufacturer $20,000 . . . Upgrading *and* standardizing may very well push up chemical pump costs—until ultimate cost-reduction benefits of standardization can be passed along . . .

If you're looking for nuclear training, don't expect to get it by taking a curriculum on that subject, was the consensus of a panel of educators . . . Instead, stay with one regular "discipline," take advanced math and physics, you'll then be able to handle the radiation effects adequately . . . **How to train biochemical engineers** received an hour's impromptu discussion, with G. G. Brown recommending incorporation of necessary information at various stages in regular courses rather than using electives . . . **President Dodge's** remarks at banquet favored same "incorporation" solution to general problem of how to add more training to the Ch.E.'s curriculum . . .

Computor-solving of engineering problems with digital machines often involves myriad steps—example, a dry air cooling calculation requires 30 steps, and these increased to about 1200 through introduction of moisture . . . while *analog* machines are often simpler, digital can go into more complicated matters, are more flexible, will be most useful once the engineer and mathematician have ironed out the working kinks (Roberts, Institute Lecturer, and Beutler, both Du Pont) . . .

Taking a top UN job means becoming —temporarily—a "citizen of the world," advised Walt Whitman, Conference Secretary General of the UN Geneva Conference on Peaceful Uses of the Atom, and newly elected President of the Institute for 1956 . . . **Himself a master** of diplomacy, Whitman explained his technique for getting along with engineers of other nations . . . Involves "putting one's self in the other fellow's place, speaking concisely, *never* working through political channels." . . .

Nuclear engineering division plans **Philadelphia Meeting and Exposition** Sept. 28-Oct. 5, 1956; major theme: **Fuel Cycle** . . .

A new division of A.I.Ch.E., the Heat Transfer Division, was organized, subject to concurrence of Program Committee and approval of Council . . . Meeting, called by D. L. Katz and attended by 45, hassled pros and cons . . . Basic need is for highly stimulative group to develop field of heat transfer in accordance with the needs of the chemical engineer . . . Katz is to be chmn., Churchill (also U. Mich.) secy.-treas. Interested? Write S. W. Churchill at Ann Arbor . . .

Bubbles and drops are often at the centers of the essential action of processes . . . Equipment designers long have had to cope with uncertainties as to size, rate of rise, and rates of heat or mass transfer to and from these small particles of material-in-process. Major advances reported in Kintner's symposium on the subject will lessen the need for pilot plant experimentation . . .

Professionalism among chemical engineers took a long leap forward at Detroit . . . At least, the profession now has a set of standards ("Professional Standards," *C.E.P.*, Nov. 1955). But like all codes of conduct, big or small, the standards are only valuable if people become fired with the desire to improve their lot by adopting its essentials . . .

The role of technical societies with respect to industry is closely tied to professional goals—this was consensus of a symposium on subject. But decisions as to whether to belong or not to belong (to a society), go or not to go (to a meeting) still rest with the individual . . . However, employers can encourage joining with considerable benefit through strengthened professional attitudes and standing of their engineers . . .

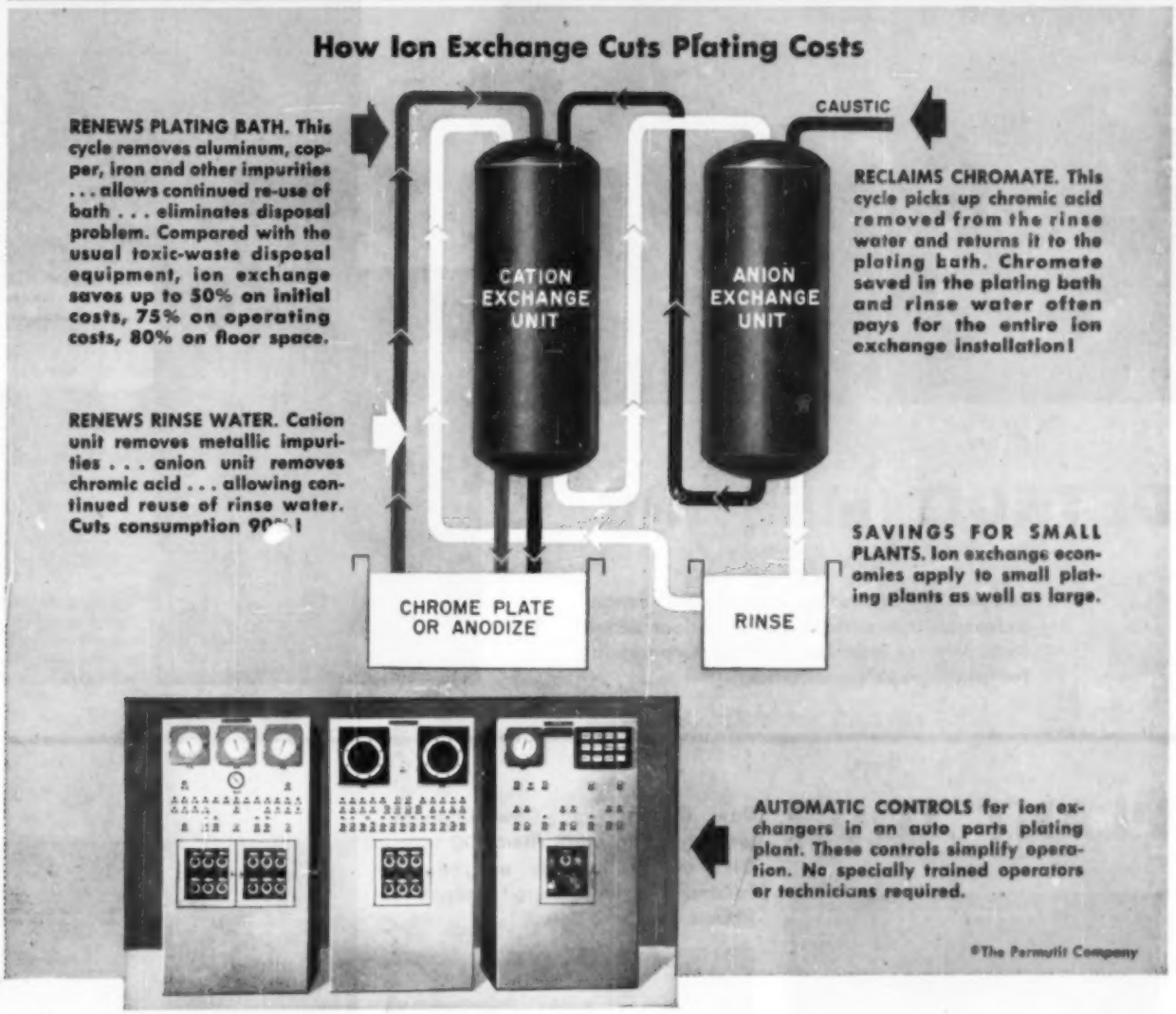
A water-conscious industry is what is developing in our nation these days . . . Affecting everything from plant location to economics of operation, water management has come to be, with GE (and other big and small firms), a formalized procedure involving conservation, re-use, waste recovery, etc. . . . In 1953, the 132 GE plants used $2.6 million worth of water . . . this would be $1.7 million more but for water management . . .

Liquid metals as heat transfer agents are on the upswing of interest (one major eutectic is liquid at room temperature) arising from their use in nuclear reactors pointing up our need to know more about their physical behavior under chemical processing conditions . . . At Prof. Bonilla's symposium, such factors as high temperature, metal droplets in an immiscible liquid, metal dissolving its containing wall, and high velocities of circulation, were treated . . . Bonilla heads another nuclear session at the Cleveland Nuclear Congress . . .

Aid to **those who buy and design evaporators** was ministered by a session of industry experts (Swenson, Rodney Hunt, and Buflovak on builder's side, International Salt for the users) . . . Two of the four speakers classified equipment presently available as to its specialized qualities and according to how used by purchasers . . . Other speakers (Kohlins and Englander, Buflovak) gave economic vs. technical relationships (watch for this in *C.E.P.*) . . . The salt people related their experience in an extensive modernization of facilities.

Boost to chemical engineering science was delivered by Prof. Pigford (U-Del.) in Professional Progress Award Lecture on kinetics of gas absorption and chemical reactions . . . "When a gaseous molecule dissolves and eventually forms a chemically reacted product, intermediate stages occur . . . only the past two or three years that the (rate factors) involved have received real attention . . . too satisfied with the treatment of gas absorption . . . all right as long as the process designer didn't attempt to go into actual details of what goes on in the process (being created) . . ." Which means the opening of another chemical frontier to stir the imagination of trained men who know what can be achieved, what fabulous products created for man's benefit, through our advancing ability to use our art of scientifically predictable techniques to combine the heretofore uncombinable isolated processing hints into scientific products of the imagination.

PROCESSES: Ion exchange "swaps" chemicals in solution at high speed . . . purifies, recovers, concentrates, separates. An example:


How Ion Exchange Cuts Plating Costs
RENEWS PLATING BATH. This cycle removes aluminum, copper, iron and other impurities . . . allows continued re-use of bath . . . eliminates disposal problem. Compared with the usual toxic-waste disposal equipment, ion exchange saves up to 50% on initial costs, 75% on operating costs, 80% on floor space.
RENEWS RINSE WATER. Cation unit removes metallic impurities . . . anion unit removes chromic acid . . . allowing continued reuse of rinse water. Cuts consumption 90%!
CAUSTIC
CATION EXCHANGE UNIT
ANION EXCHANGE UNIT
RECLAIMS CHROMATE. This cycle picks up chromic acid removed from the rinse water and returns it to the plating bath. Chromate saved in the plating bath and rinse water often pays for the entire ion exchange installation!
SAVINGS FOR SMALL PLANTS. Ion exchange economies apply to small plating plants as well as large.
CHROME PLATE OR ANODIZE
RINSE
AUTOMATIC CONTROLS for ion exchangers in an auto parts plating plant. These controls simplify operation. No specially trained operators or technicians required.
©The Permutit Company

Ion Exchange Cuts Process Costs

A fast-growing unit process, ion exchange is already a multi-million-a-year business. Here are some of the jobs it's doing now:

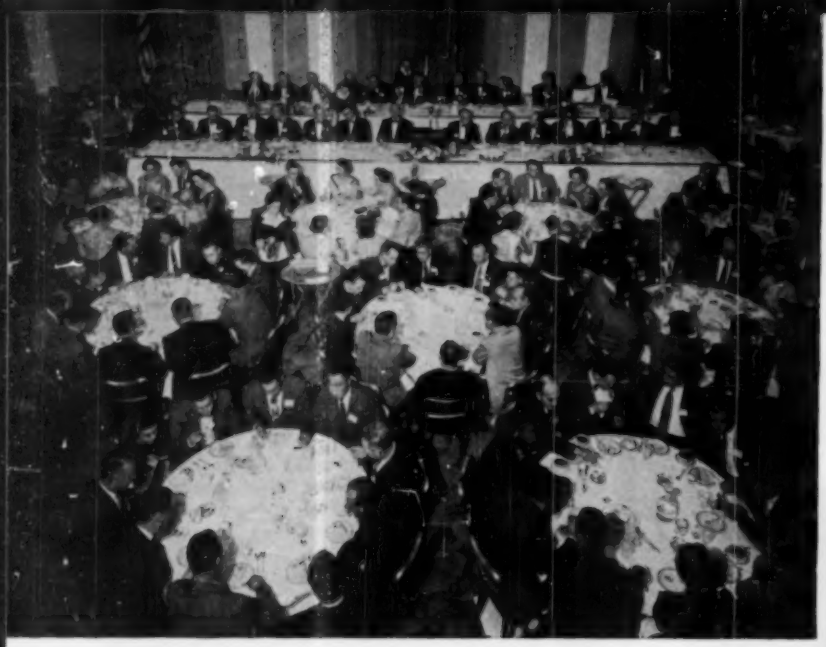
• **Water Conditioning** is biggest ion exchange use . . . removing scale-forming hardness for homes, steam boilers . . . softening cooling water so it can be used over and over . . . purifying process water for TV tubes, synthetic fibers . . . reclaiming waste water (e. g. chromate plating rinses).

• **Process applications:** Removing impurities from formaldehyde, glycerin, alcohol, plating baths and other chemicals, also wines, sugar solutions; recovering copper and zinc from rayon plant wastes; concentrating metals in dilute solutions such as plating rinses, mine waters; removing iron from phosphoric acid pickling solutions; producing colloidal silica used in textiles, waxes, foundry molds; making antibiotics, e.g. streptomycin, and other medicinals.

• **Largest manufacturer** of ion exchange equipment, The Permutit Company (N. Y.), got a head start in ion exchange with the natural zeolites first used in water conditioning . . . now manufactures highly efficient synthetic resin ion exchangers of all types. Permutit is the only U. S. producer of both resins and equipment. Making both allows proper "mating" of the two . . . enables Permutit to take responsibility for performance of the entire installation.

If you have a problem involving the recovery, concentration or separation of chemicals in solution, a Permutit ion exchange process can probably help you. Address: The Permutit Company, Dept. CEP-12, 330 West 42nd St., New York 36, N. Y.

PERMUTIT®
rhymes with "compute it"
ION EXCHANGE
for Water Conditioning • Chemical Processing



Pressroom scene, with Leon Chrzan (P-R ch.) and Ted Carron (seated, Tech. Progr. ch.)

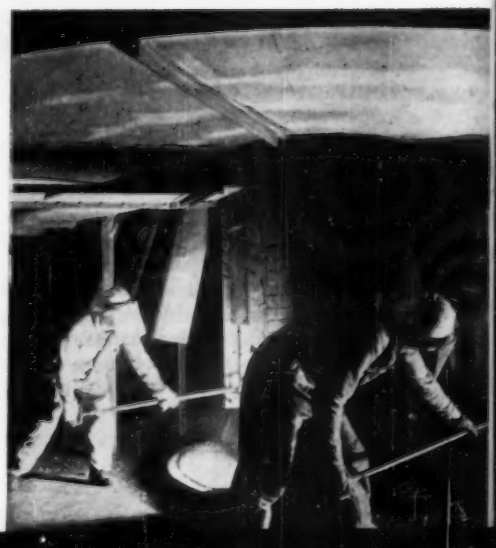
Outgoing President Dodge pins official symbol of office on President-Elect Whitman.

DETROIT MEETING

Temperatures hovering in the 10-20° range sharpened the enthusiasm for indoor activities. We are indebted to Ethyl Corporation for photographic assistance.

PLANT TOUR

Dow Corning and Dow Chemical were hosts to more than 200 members of the Institute on the day following the Detroit meeting. Photos courtesy Dow.



Upper left: Registering.

Lower left: Guests being welcomed by W. R. Collings, president of Dow Corning Corporation, one of the host firms.

Center, above: Group 2 boarding buses for nearby Dow Chemical Co.

Upper right: In a lab.

At Dow Corning, this furnace was seen producing 98% Si metal, basic ingredient for silicones.

WJBK-TV's Murray Young films Dodge, Whitman and Katz for the late Tuesday newscast.

Those who made the meeting possible; *standing*, D. W. Schroeder—Plant Trips, Stanley Gavern—Hotels, Wendell George—Hotels, R. V. Laitner—Hotels, Phil Sauer—Hotels, John Olsen—Finance, W. J. Leisten—Registration, C. W. Hamilton—Registration, S. J. Hornak—Hotels, H. C. Gudebski—Plant Trips; *Seated—Left to right*, E. W. Tillitson—Printing, Leon S. Kowalczyk—Plant trips, Mrs. P. A. Lenton—Ladies Committee, Leon Chrzan—Public Relations, John F. McAnulty—Registration, C. P. Cunningham—Entertainment, Phil Lenton—Chairman, Detroit Section, Harvey Merker—Honorary Chairman Committee on Arrangements, L. W. Gleekman—Secretary, E. Garelis—Technical Program, J. P. Leslie—Finance, John Shior—Finance, Mrs. L. R. Chrzan—Ladies Committee, D. W. Anderson—Hotels and Meeting Facilities; *Absent*, O. E. Kurt—General Chairman, H. G. Donnelly—Student Program, D. C. McGehee—Transportation.

Ladies session.

What most chemical engineers do at an Institute meeting.

In one of the plant yards.

Looking over Oliver rotary filters in the Epsom salt plant.

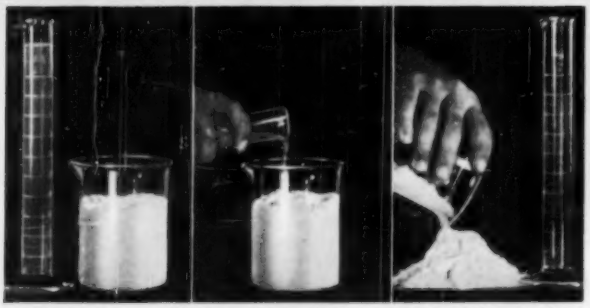
T. B. Shudark (center), production supt. of Calcium Magnesium Div., Dow Chemical.

Saran Wrap packaging.

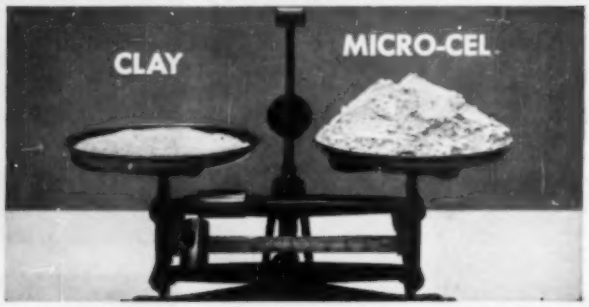
End of a pleasant trip; reboarding special train for return to Detroit.

Announcing... a new line of synthetic

The powder that flows like a liquid
Micro-Cel (as compared with clay in photo) will greatly improve the flowability of many products . . . maintains its free-flow properties even under the most adverse storage conditions.



Absorbs up to 6 times its weight in water—Micro-Cel remains a free-flowing powder even after absorbing more than twice its own weight of liquid.



High bulk . . . loose weight density as low as 5 lb. per cu. ft.—Micro-Cel "fluffs up" any compound with a minimum addition.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville MICRO

calcium silicates developed by Johns-Manville Research

MICRO-CEL...

Check its different combination of properties . . . it may hold the key to lower costs and product improvements in your process formulations.

Johns-Manville's new Micro-Cel line can produce many desirable effects as the following examples illustrate.

Absorption of Liquids—Micro-Cel will absorb 1 to 2½ times its weight of liquids and still remain a free-flowing powder.

Uniform Dry Dispersion—Different Micro-Cel grades with particle sizes as low as .02 microns and particles of rounded to spherical shape provide fast, uniform blending without segregation.

Viscosity Control—Various degrees of viscosity up to a paste or semi-solid can be achieved by adding relatively small quantities of Micro-Cel.

Anti-caking Agent—Micro-Cel's high absorption and fine particle size of less than 0.1 micron effectively control caking of deliquescent products and insure flowability even after prolonged storage.

Bulking Agent—A small percentage of Micro-Cel materially increases the bulk of dry powders—allows control of package density.

Pigment Extender—Micro-Cel's surface characteristics, fine particle size and large specific surface, combined with inertness, indicate its value as a pigment extender.

Suspension Agent—Micro-Cel's different combination of properties provides aid in suspension of heavier solids.

Flatting Agent—Micro-Cel's high absorption, fineness and particle shape indicate its value as a flatting agent.

Reinforcing Pigment—The combination of fine particle size, particle shape, and wetting characteristics suggests the value of Micro-Cel as a reinforcing pigment.

Some Proven Uses

Micro-Cel has already been proven as offering outstanding advantages as an absorbent-grinding aid for high liquid concentrate insecticide wettable powders, as an anti-caking agent in fertilizers, insecticide dusts, cleansers and detergents. Additional uses are being explored in Johns-Manville's Research Center.

Chemical Composition

Developed after years of research and experimentation by Johns-Manville, Micro-Cel is produced by the chemical combination of lime and diatomaceous silica under carefully controlled conditions. As a result, specific grades are available offering a wide range of physical properties.

RANGE OF PHYSICAL PROPERTIES

Color	white or off-white
*Absorption, % by weight	
Water	300-600
Oil	275-500
Bulk density, lb./cu. ft.	5-15
Ultimate particle size, micron	.02 to .07
pH	8.0-10.0
Moisture (free), wt., %	5-8
Refractive index	1.52-1.55
Available surface area, sq.m./gm.	95-175

*Will absorb 1 to 2½ times its weight in liquid and remain a free-flowing powder.

Samples Now Available

Micro-Cel is now available for laboratory and production evaluation. Write to Johns-Manville for further data on your specific problems. An engineer from J-M's Celite division will be glad to work with you in adapting Micro-Cel to your own particular requirements. Mail coupon today.

Johns-Manville, Box 60, New York 16, N. Y. CEP 12
In Canada: Port Credit, Ontario

☐ Please send additional data and samples of Micro-Cel. I am interested in formulating the following products:

_____

☐ Please have local representative contact me

Name_____

Position_____

Company_____

Address_____

City_____ Zone____ State_____

-CEL **SYNTHETIC CALCIUM SILICATE**

A PRODUCT OF THE CELITE DIVISION

BOOMING RESEARCH IN PROCESS INDUSTRIES

Process industries show again their basic belief in the adage—In research lies progress.

Another wave in the continuing process of growth in research facilities within the process industries has been with us for some months. New buildings, new organizations, new expansions are appearing just about around every corner.

In the last few months alone, no less than 20 major research installations have gone into operation, under construction, or been announced as in the planning stage.

In the basic chemical field, U. S. Industrial Chemicals Division of National Distillers has built a $500,000 pilot plant addition to its basic Cincinnati research facilities. Sodium is the key at U.S.I., and the new lab will concentrate for now on the new U.S.I. Isosebacic acid.

Functional utility is keynote at Universal Oil Products' Des Plaines laboratory.

Food Machinery & Chemical is underway with a Central Research laboratory for its Chemicals Divisions. Being built near Princeton, N. J., the new laboratory will concentrate on basic long-range research for the Divisions as a whole.

Food Machinery & Chemical's main building at Central Research laboratory.

At Phillips Chemical, a Sales Service Laboratory for the company's new rigid polyethylene, Marlex, is in the building stage, will be built adjacent to the parent company's (Phillips Petroleum) new Chemical Research Laboratories, also under construction at Bartlesville, Okla.

Du Pont's sales development and technical service lab at the Film Department, Chestnut Run, near Wilmington, is now in operation, cost $1 million, will work on the company's various films, including Mylar polyester film.

For Petroleum—four highlight entries. Multi-million dollar Research Laboratory of Universal Oil Products at Des Plaines, Ill., stresses maximum space utilization and functional convenience, is the result of five years' study and experimentation.

Continental Oil has a $500,000 pilot plant building designed by the company to explore petrochemical production methods.

Cities Service is planning a new product research center to concentrate on developments in fuels and lubricants.

Ethyl Corp. offers a new unit in its chain of gasoline testing laboratories, this one at Houston, Tex.

In rubber, the big news is the race for "synthetic" natural rubber. Goodrich-Gulf Chemicals is ready to construct a pilot plant at Avon Lake, O., for detailed investigation of the company's entry in this field.

Major development in metals, is the expansion of Electromet's (Division of Union Carbide) Metals Research Laboratories at Niagara Falls, N. Y., by addition of a Chemical Engineering Bldg. of ultra-new design for operation and future expansion.

Another advance is Jones & Laughlin's just-opened Research Laboratory in Pittsburgh.

High-bay at Electromet's Metals Research laboratory.

Biochemicals' latest lab is the bioscreening lab at the Richmond, Calif., research center of California Spray-Chemical.

(*Continued on page* 44)

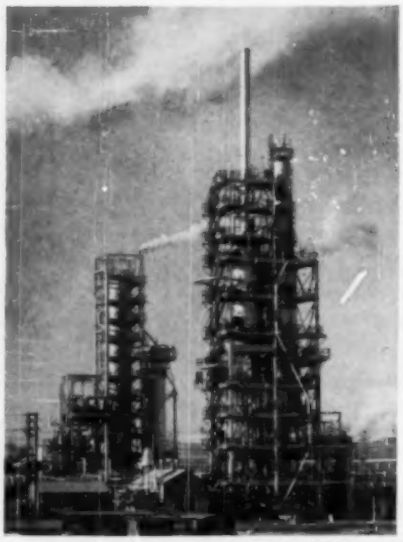
FLUID COKE IN FIRST COMMERCIAL USE

The new oil-derived fuel, Fluid Coke, is now ready for use in commercial power generation.

At the Essex Generating Station of Public Service Electric and Gas Co., Newark, N. J., Fluid Coke is to be used for the first time, commercially, to produce electric power.

Fluid Coke, a material resembling black sand made during the manufacture of gasoline in a new refinery process of Esso Research and Engineering Co., was developed as a means to reduce or eliminate the production of residuum from crude oil, and to up the production of gasoline at the same time. (For full details of the process see *CEP* April, 1955, pp. 167-173.)

At Public Service the Coke will be burned in modern boilers, will be handled by conventional ball grinding mills, conveyors and boilers, all of which were found satisfactory in a series of tests made by Public Service on 1000 tons of the Fluid Coke. Public Service has contracted to take the full output of Esso Standard Oil Co.'s recently completed unit at its Baltimore refinery. This is some 170 tons/day, will replace about 750 bbls./day of heavy fuel oil.



The world's first commercial Fluid Coker (right) towers 196 ft. at Carter Oil Company's Billings, Mont., refinery. The unit takes low value residual oil and breaks it down for conversion to motor and burner fuels.

At present other power companies are studying the use of Fluid Coke, will have their eyes on results from Public Service. In addition, Fluid Coke is being examined for possible use in the manufacture of fireplace and outdoor briquettes, electrodes for aluminum production, calcium carbide, cement, metals and other products.

At present only the Esso Baltimore unit, and the original Esso unit at Billings, Mont., are in operation. Esso has licensed four other companies, and the process is available for licensing by oil refiners anywhere in the free world.

With its demonstrated ability to help refiners get 10% more gasoline from a barrel of crude oil, and to reduce the heavy residuum, Fluid Coking holds a great deal of interest for refiners, results of Public Services venture in its use bear watching with considerable attention.

Typical of the high-production, cost-cutting Baker Perkins chemical processing equipment is this Universal Vacuum Mixer, size 15 TWEM. Working capacity 100 gallons; total 175 gallons. Constructed of Stainless Steel, jacketed for 125 psi heating or cooling.

BAKER PERKINS INC.

Chemical Machinery Division • Saginaw, Michigan

326

two famous names join forces . . .

U S G S

BELMONT

for greater service to Industry

● The consolidation of product lines and sales service facilities of the United States Gasket Company and The Belmont Packing & Rubber Company creates a new major source for all your gasket, packing and allied product requirements—*plus* the most compiete line of TEFLON and KEL-F stock offered to Industry, today.

It brings together the specialized engineering and manufacturing experience, and enlarged, modern production facilities of these two companies to better serve your standard and special needs.

It brings together the nationwide Industrial Distributor organizations of both companies—backed by an enlarged staff of U. S. Gasket-Belmont Packing field representatives—to make these combined lines even more readily available and profitably employed in every industrial community.

UNITED STATES GASKET COMPANY, Camden 1, N. J.

THE BELMONT PACKING & RUBBER COMPANY, Phila. 37, Pa.

U.S. GASKET—BELMONT PACKING PRODUCTS INCLUDE:

PACKINGS: MOLDED RINGS—Teflon, Asbestos Cloth, Duck. SPIRAL OR COIL PACKING—Braided and Twisted Asbestos, Braided Teflon, Extruded Teflon, Asbestos Fabric, Duck and Rubber, Flax and Jute, Metallic and Semi-Metallic. PLASTIC PACKING—Teflon, Shredded Asbestos, Metallic. SHEET PACKING—Asbestos, Fibre, Cork, Rubber, Synthetic Rubbers, Metallic. O-RINGS, BACK-UP RINGS, V-RINGS, CUPS, U-RINGS, FLANGE PACKINGS—Teflon, Leather, Rubber, Rubber Reinforced. **GASKETS:** Spiralwound, Molded Teflon, Kel-F, Teflon-Jacketed, Metal-Asbestos, Asbestos, All Metal. **TEFLON SPECIALTIES:** Expansion Joints, Flexible Couplings, Adaptors, Reducers, Rotating Mechanical Seals. **TEFLON & KEL-F STOCK:** sheets, tape, rods, tubing, bars, cylinders, fabricated parts.

U. S. GASKET • BELMONT PACKING

BOOMING RESEARCH

(*Continued from page* 42)

Looking at instrumentation firms, Fischer & Porter has two new research installations—a fluid mechanical laboratory to be ready in the spring, and a chlorination research and development laboratory.

Fibers move on with Celanese's new development laboratories at Charlotte, N. C., the most complete development lab ever attached to a textile marketing operation. Basic here is centralization and modernization of once scattered facilities.

Rayonier joins the march with an Eastern Research Laboratory in New Jersey, to be staffed by some 150 scientists.

Research and development companies have been building and expanding as fast or faster than other companies. Latest to feel the need for space are Dallas Laboratories, Dallas, Tex., and DeBell & Richardson, Hazardville, Conn., a specialist in plastics.

Precision products, for both industrial and defense use, are moving ahead with Gruen Watch Co.'s new research and development company which expects to build in the near future.

Perhaps biggest single research advance is General Electric's $5 million Metals and Ceramics Laboratory recently gone on stream at Schenectady. General Electric also has opened a new radiation laboratory costing $300,000, just one of many research developments in the nuclear field over the past year.

These are just the high spots of a few months, new research facilities seem to be endless. For the engineer the meaning is clear. New research means new products, improved products, and the need for engineers to work on these new and improved products.

"UNRECOVERABLE" OIL

Engineers develop new method of recovering highly viscous oil deposits long considered unrecoverable.

The possibility that the oil reserves of this country, perhaps of the entire world, may be fortified with billions of barrels long considered unrecoverable, is the result of two years' laboratory, pilot plant, and field testing work by the engineers of Worthington Corp., an expert in this field.

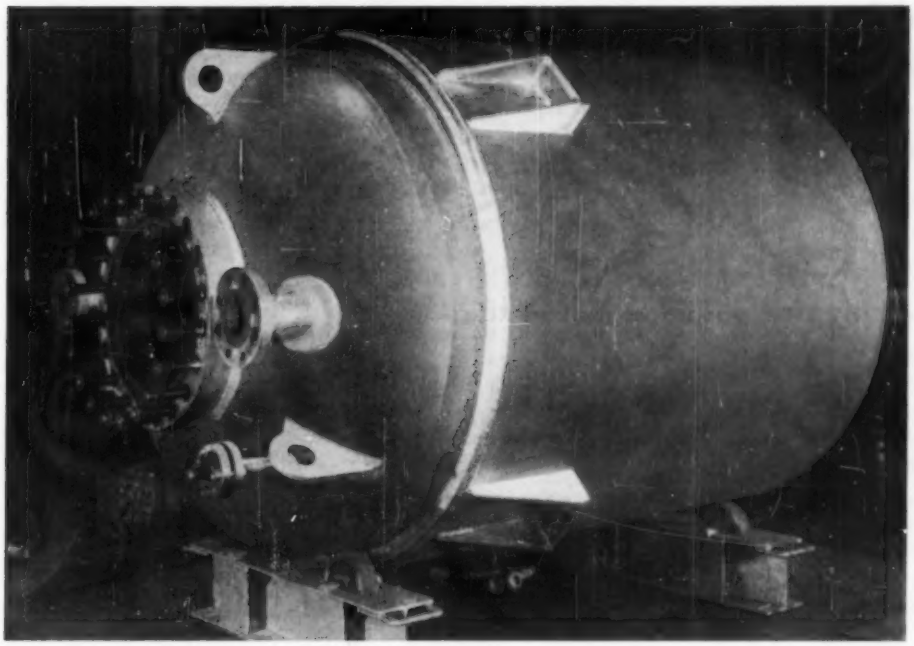
According to Worthington's engineers, the new method may make it possible to extract close to 90% of the known oil reserves, compared to the

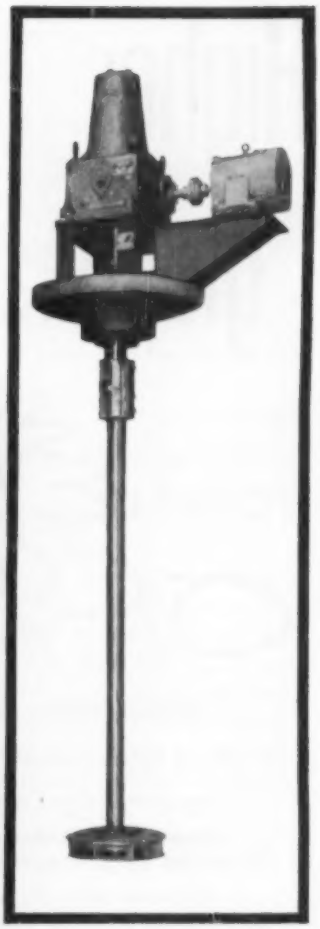
(*Continued on page* 46)

Ammoniation Autoclave built by Bethlehem

SAVES USER MONEY 3 DIFFERENT WAYS:

❶ Lower First Cost ❷ Less Maintenance
❸ Minimum Downtime





Agitator ▲

◀ *Vessel*

the reaction vessel shown here, complete with agitator and drive,

was a replacement designed and built by Bethlehem to assure lower first cost, less maintenance, and fewer shutdowns.

First cost was lowered by use of a lighter shell made possible by X-ray to increase weld efficiency, and by annealing, to permit higher design stresses.

Low maintenance costs were made possible by use of a stellited shaft in the stuffing box to avoid scoring and wearing of shaft by packing. Heavy duty gear reducer, with minimum bearing runout, drives the agitator shaft. Replacement or adjustment of bearing can readily be made without lengthy shutdowns and expensive repairs.

Downtime from cracking and shattering of agitator impeller due to embrittlement, was avoided by the use of alloy steels for fabrication.

This vessel is an example of Bethlehem's comprehensive approach to one manufacturer's very special equipment needs. This same complete responsibility, backed by engineering design and manufacturing techniques, can be applied to your needs.

Write us today
to have one of our field engineers call.

BETHLEHEM FOUNDRY & MACHINE CO.
Process Equipment Division
BETHLEHEM, PENNSYLVANIA

Higher yields...

YORKMESH DeMISTERS permit higher yields—

In refinery vacuum towers:

Increased yield of gas oil by cutting deeper into the bottoms.

Increased yield of liquid products in the cat cracker due to decreased carbon and asphaltic materials in the gas oil.

Increased yield of gasoline due to high catalyst activity, which is maintained since Yorkmesh DeMisters remove vanadium and nickel compounds which are otherwise carried over by entrainment into the gas oil product.

Yorkmesh DeMisters give increased yields of liquid products from wet gas.

In evaporators, Yorkmesh DeMisters give increased yield by preventing loss of product by entrainment to the condenser.

When installed in new or existing process vessels, these wire mesh entrainment separators improve process efficiency, increase throughput capacity, improve overhead quality, reduce product contamination, or avoid air pollution.

CLEAN Separation

As vapors or gas flow through the wire mesh, the entrained liquid impinges on the wire surfaces and is coalesced into large drops which run off by gravity flow. The clean vapor passes overhead.

Yorkmesh DeMisters provide clean separation between liquid and vapor in:

Vacuum Towers • Distillation Equipment
Gas Absorbers • Scrubbers • Evaporators
Knock-Out Drums • Steam Drums

YORK

OTTO H. YORK CO. INC.
6 CENTRAL AVENUE, WEST ORANGE, N. J.

INDUSTRIAL NEWS

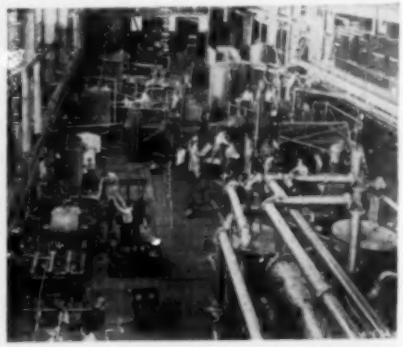
"UNRECOVERABLE" OIL

(*Continued from page* 44)

present estimated possibility of from 40-70%.

The specific two-year field test just completed was done in co-operation with the Forest Oil Corporation, Bradford, Pa., in a shallow field in southeastern Illinois. The field contained highly viscous oil previously considered unrecoverable by any known method. The main reason for the "unrecoverable" label was that the bottom temperature of the field, some 50° to 60° F., was too low to allow the heavy oil to run freely or to be driven from the sandy rock and other natural formations entrapping it.

Worthington's idea was to introduce heat, warm up the soil, and thus bring it to the surface. To this end the company designed, engineered and built special equipment. In this particular field, hot combustion gases and steam were



Basic research on the new oil recovery method goes on at Worthington's Research and Development laboratory in Harrison, N. J.

the driving agents, and hot air was the oxidizer for underground combustion, although the equipment was designed to allow the driving and reactive agents to be changed according to geological conditions and the viscosity of the crude.

After treatment of the field, core tests revealed 80% of the oil content, originally 24,000 bbls./acre, was recovered through four wells drilled in the corners of a 110-foot square. Of the remaining 20%, some 10% was used up in the process of underground combustion, and another 10% driven into the adjacent formation where it will be recovered in a large-scale operation.

According to Hellmuth Walter, Worthington's Director of Research, the method should prove highly profitable for operations covering 100 or more acres. The economic potential in bringing so much oil back into the recoverable reserves is obvious in this particular stage of the business and national economic picture.

Pumping Progress Report

FOR HYDRAULIC ENGINEERS

An advertisement prepared by the Aldrich Pump Co. Member of Hydraulic Institute, U.S.A.

UREA PRODUCTION, like many other chemical processes, presents difficult pumping problems. Urea slurry is both corrosive and erosive. Either condition can cause serious operational headaches; together they spell trouble for both design and maintenance engineers.

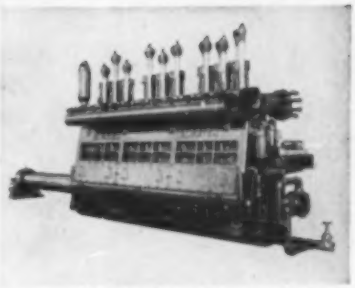
PUMPING UREA SLURRY was the problem given to the Aldrich Pump Company Engineers by one of the foremost producers of urea. Our solution was effective. We recommended...

A 6" STROKE DIRECT FLOW TRIPLEX with several material of construction modifications. Porcelain plungers were used instead of the usual hardened alloy steel. The entire fluid-end was made of Hastelloy B, but Direct Flow Fluid-End construction was maintained to give minimum cost of parts replacement in the event of unavoidable corrosion or erosion damage.

ALDRICH DIRECT FLOW DESIGN offers many advantages to reciprocating pump users. Two right angle turns are eliminated in the fluid-end block. The liquid being pumped travels in a straight line, on a horizontal plane, from the suction to the discharge manifold. Reduced space between valves results in higher volumetric efficiency and extra close valve clearance.

SECTIONALIZED FLUID-ENDS also afford greater economies of maintenance. Valves can be removed for inspection or replacement without special tools or equipment. Individual sections of the fluid-end can be replaced at a fraction of the cost of conventional type fluid-ends.

DATA SHEET 67A illustrates and describes the Aldrich 6" Stroke Direct Flow Pump Series. This Series includes Triplex, Quintuplex, Septuplex and Nonuplex Pumps, ranging in power from 300 to 900 hp. Aldrich Engineers are available to help you solve your tough pumping problems. Address your request to: The Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.



6" Stroke Direct Flow Aldrich Pump.

...for your tough pumping problems specify ALDRICH

Long, trouble-free service life and low cost are assured features of this pump. It is characterized by the unique Aldrich Direct Flow design and rugged construction that have made Aldrich Pumps famous. Modifications can be made to adapt the unit to many types of service. Sectionalized fluid-ends afford fullest economy in maintenance and repair.

TYPICAL CHEMICAL APPLICATIONS FOR ALDRICH PUMPS:

caustic solutions	fatty acids
anhydrous ammonia	nitric acid
amine solution	cobalt solutions
viscous liquids	acetic acid
nickel catalyst	abrasive slurries

Send for specific data in new catalog. Or, if you have a special problem, ask one of our representatives to call.

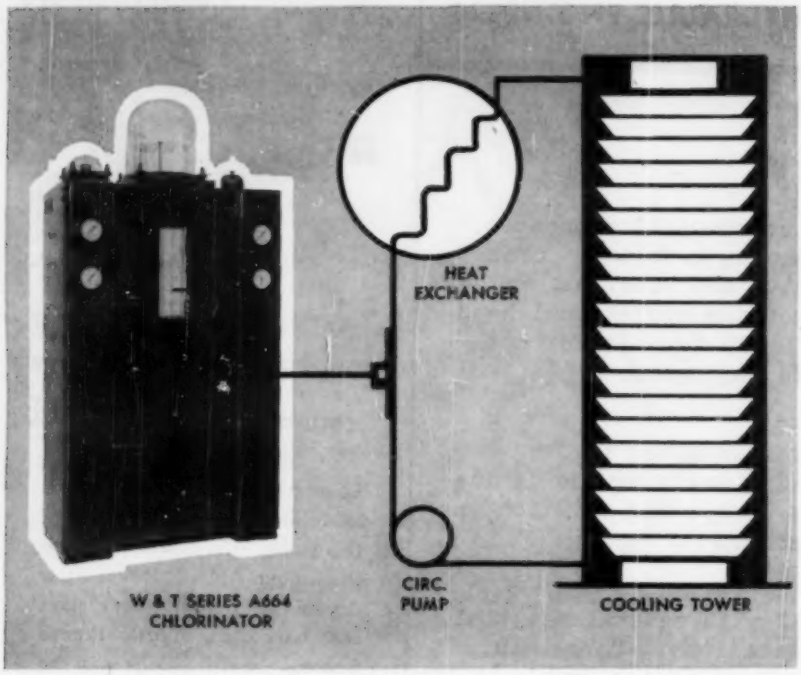
THE ALDRICH PUMP COMPANY

Originators of the Direct Flow Pump

20 GORDON STREET
ALLENTOWN, PA.

Representatives in principal cities

Slime Control...



...Chlorination of Cooling Water Circuits

Heat transfer losses caused by slime formation on condenser and heat exchanger water-side surfaces can be eliminated by chlorination of the cooling water. Water and air-borne organisms—the cause of slime formations—are effectively and economically controlled by Wallace and Tiernan chlorination systems.

The Wallace and Tiernan Series A-664 Chlorinator shown above is one of a complete line of W&T chlorination equipment, designed to give dependable chlorination at all feed ranges. It is used at large plants where cooling water chlorine requirements call for a durable high capacity unit.

We Invite Your Inquiries

Technical information on cooling water chlorination is available in our free booklet, RA-2061-C. Bulletins on chlorination of industrial process water and industrial waste treatment are also available. Write us for your copy.

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CD-40

INDUSTRIAL NEWS

CONTINUOUS RUBBER RECLAIMING

Cuts time required, gives better, cheaper product.

A continuous process for reclaiming rubber has been developed by B-I-F-Industries, Providence, R. I. Solving the problems of accurate proportioning and feeding of crumb rubber, oxido-plasticization agents and softening oils, the new method is claimed to cut process time from 10 hours to a few minutes.

In the process old tires are cracked, screened, all metal and fiber removed. The resulting crumb is further screened and sifted to remove non-magnetic material, and then fed on a gravimetric belt feeder to a special double screw mixer. Special proportioning pumps continuously meter oxido-plasticization agents (mercaptans, monosulphides, disulphides, etc.) and softening oils into the same mixture.

The resulting pre-mixed crumb is continuously fed into a 12-in. screw extruder having heating and cooling zones, where the rubber crumb is compressed, worked mechanically and heated to 350° F., under which conditions devulcanization takes place.

In addition to the time saved, other advantages claimed for B-I-F's method are: more product with less power; elimination of expensive, variable manual operations; a more uniform quality of product; and economical recovery of by-products.

RIGID POLYETHYLENE BY HERCULES

Latest entry into the mushrooming rigid polyethylene field.

Construction of a $10 billion, 30 million pound high-molecular weight polyethylene plant at Parlin, N. J., will bring Hercules into what is, for it, an entirely new field of chemical manufacture.

Operating the Ziegler process under license from Karl Ziegler, developer of the rigid polyethylene, Hercules expects to be in production late in 1956, but will offer to supply the material early in 1956 through a supply arrangement with Farbwerke Hoechst AG in Germany, one of the first companies licensed by Ziegler. In addition, the agreement with Hoechst calls for continuing exchange of research information between the companies.

The new polyethylene has aroused extreme interest, is expected to open new fields rather than replace ordinary polyethylene.

C. J. McFarlin, President, Air Reduction Chemical Company, a division of Air Reduction Company, Incorporated.

McFarlin of Airco

Integration, location and lots of vinyl acetate

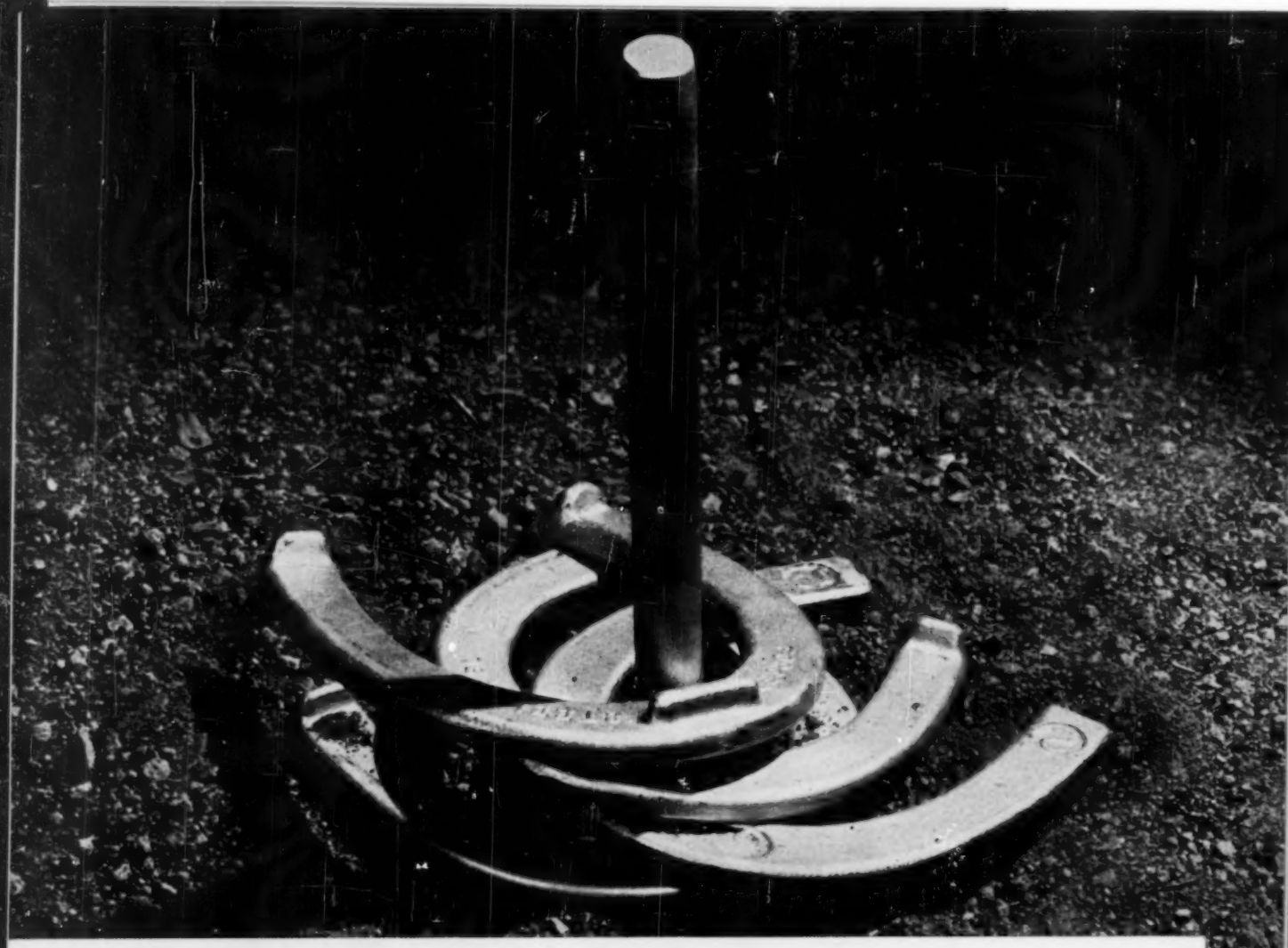
"Our new vinyl acetate plant at Calvert City is another development in Air Reduction's chemical expansion. The Lummus Company is engineering and constructing this plant for us and will bring it on stream early in 1956."

In the midst of an abundance of available power, natural gas, water transportation and a host of related chemical products, Lummus is engineering and constructing an integrated 30,000,000 lb. per year vinyl acetate plant for Air Reduction Chemical Company, a division of Air Reduction Company, Inc. Adjacent to Air Reduction's National Carbide Division, it receives pipeline acetylene and converts it into vinyl acetate which goes principally into polyvinyl acetate emulsions, used in adhesives, latex paints and textile finishes — and polyvinyl alcohol, used for adhesives and textile finishes.

At Calvert City, in addition to this new Air Reduction plant, Lummus is also building a $6,000,000 high pressure acetylene derivatives plant for General Aniline & Film Corporation which is a "first" in its field. What better examples could be given to show that Lummus is ready, willing and able to design, engineer and construct your next chemical plant.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, N. Y. *Engineering & Sales Offices:* New York, Houston, Montreal, London, Paris, The Hague, Bombay. *Sales Offices:* Chicago, Caracas. *Heat Exchanger Plant:* Honesdale, Pa. *Fabricated Piping Plant:* East Chicago, Indiana.

the chemical engineers'



POSITIVE PERFORMANCE

An important cost reduction factor in the production of chlorine and caustic soda is the positive performance of GLC ANODES.

ELECTRODE GLC DIVISION

Great Lakes Carbon Corporation

GRAPHITE ELECTRODES, ANODES, MOLDS and SPECIALTIES

ADMINISTRATIVE OFFICE: 18 East 48th Street, New York 17, N.Y.

PLANTS: Niagara Falls, N.Y., Morganton, N.C.

OTHER OFFICES: Niagara Falls, N.Y., Oak Park, Ill., Pittsburgh, Pa.

SALES AGENTS IN OTHER COUNTRIES: Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada
Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo, Japan

Postage Will Be Paid by Addressee

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the chemical engineers'

DATA SERVICE

and

GUIDE

to significant developments in

- **EQUIPMENT**
- **MATERIALS**
- **SERVICES**

developments of the month-

108. New, Detailed 16-page Catalog describes thickeners, clarifiers, agitators.

In its new 16-page bulletin, Hardinge Co. has come up with what is very nearly a handbook of thickeners, clarifiers and agitators. Featuring the pictured new design of its thickener drive with "Auto-Raise," described in full detail in the catalog, the catalog goes on to give analyses of thickeners and clarifiers, including discussion of such factors as collecting mechanisms, support structures, drive mechanisms, center column mechanisms, materials of construction, feed and discharge arrangements, and a special and practical formula for determining tank diameters of thickeners for any given set of data.

Agitators, slurry mixers, hydro-classifiers and separators are similarly treated. Emphasis is on design and operation.

All analyses are fully illustrated with detail drawings, pictures, charts, and tables.

This catalog should prove highly valuable to all engineers with interest in this type of equipment, gives full particulars of Hardinge's line.

For further information circle number 108 on Data post card.

(Continued on page 52)

TURN THIS PAGE TO RIGHT FOR MORE . . .

HOW TO USE THIS POST CARD FOLDER

Merely encircle numbers on cards to get literature desired. On advertised products in front of magazine, fold this page out to right. For those in back, fold card strip again to right, where card strip is scored for detaching.

products-

IFC Processes. To assure minimized investment & maximum product quality with top operating economy consult Vulcan Copper & Supply Co.

3R Drum Packer. ViBrox with its exclusive mechanical rocking-vibrating motion packs more into the container. Sizes for packing containers with capacities 5 to 1,000 lb. B. F. Gump Co.

4A Process Apparatus. The Votator continuously heats or cools viscous & liquid materials at rates 6 to 10 times those of conventional batch methods. Girdler Co.

6L Turbine Pumps. Investigate Verti-Line pumps for the best in vertical pumps. See illustrations of construction features. Layne & Bowler Pump Co.

7A Plant Construction. A complete custom fabrication service for process units or complete plants, from blueprints until you are "on stream." Nooter Corp.

8A Valves. Even manufacturers of various types of soaps & cleaning fluids find these valves stay tight. Made of Ni-Resist. Crane Co.

9A Filters. Snap blow on Eimco filters accomplished by introducing high pressure air at discharge joint. Equipped with scraper blade which may be moved back so as not to touch media. Eimco Corp.

10A Flow Control. Precision pumping is the subject of literature available from Milton Roy Co. Information on the latest & most advanced methods of flow control.

12L Diaphragm Valves. Virtually unlimited range of materials may be successfully handled with these valves. If you valve a "hard-to-handle" fluid consult Hills-McCanna Co.

13A Filters. Absolute purity of products such as antibiotics & pharmaceuticals is maintained in these custom built filters. Eimco Corp.

14A Speed-Lock Cover. A new concept in pressure vessel closure called Speed-Lock. Eight advantageous features. Standard on all Sparkler model MCR filters. Sparkler Mfg. Co.

15A Air Preheater. Finer control means a more uniform product with average ratings to 2 octane numbers higher. Use the Ljungstrom for heat-recovery efficiency. Air Preheater Corp.

16A Handbook. Johns-Manville provides valuable information on all their products for solving design & operating problems in this new book.

17A Process Equipment. Individualized units built on experience gained over many years. Fabrication to all ASME codes & wide range of materials. Koven & Bro., Inc.

18L Safety Heads. Improve the safety of your pressurized equipment by the use of safety heads. Information available on applications. Black, Sivalls & Bryson, Inc.

19A Valves. The unique Sealdport lubrication system surrounds the plug & body with a positive seal of pressurized lubricant. Rockwell Mfg. Co.

21A Centrifugal Pump. Radical new design permits pump to handle many industrial liquids. If you have a problem too tough for an ordinary pump investigate the Ingersoll-Rand pump.

22L Research Laboratories. Designed, engineered, & constructed to meet the designs of tomorrow by Wigton-Abbott Corp.

23A Graphite Equipment. Ten pay-off features when you use Karbate brand impervious graphite process equipment. See the list. National Carbon Co.

24A Gauges. Now a line of small-size easy-to-read gauges & receivers from Republic Flow Meters Co. Individual, independent measuring units.

25A Dowtherm. An ideal transfer medium for high temperature, low pressure heat at 700° F. unit exerts but 95 lb./sq.in. pressure. Dow Chemical Co.

26L Heat Exchangers. Uniform distillation product available through all changes in climatic conditions the year around. Maximum production insured. Niagara Blower Co.

27A Stainless Steel Tubing. Use of stainless tubing guarantees more for your money. Ask Mr. Tubes your link with Babcock & Wilcox Co.

28L Mixers. A unique split-level dispersion bowl increases the effective mixing area of this unit by 50%. Available for manual or hydraulic discharge in capacities 150 to 750 gal. Read Standard Corp.

29A Corporation Briefs. Cooper Alloy Corp. is making available literature on the products manufactured by each of their divisions. Send us your request list.

30A Process Equipment. Whether your need is for big or little equipment custom-built units are available to your specifications from Chicago Bridge & Iron Co.

31A Potentiometer. The exclusive balancing action of the Dynalog gives instant response to slightest change. Sensitivity 1/100 of 1%. Foxboro Co.

32A Intermediates. Production of nine basic intermediates from hydrocarbons & some end chemicals is performed in Girdler Co. plants. Avail yourself of their experience.

34A Ammonia. A choice of four different processes each designed for optimum efficiency at different type locations is offered by M. W. Kellogg Co.

35A Turbo-Mixers. These units perform efficiently even so tough a job as leaching titanium sponge. General American Transportation Corp. makes a Turbo engineer available to aid in solving your mixing problems.

37A Ion Exchange. This fast-growing unit process aids in solution of problems of water conditioning & other process applications. Permutit Co. produces both resins & equipment.

40A Synthetic Calcium Silicates. Announced by Johns-Manville a new line of these materials. Check Micro-Cel for its combination of properties.

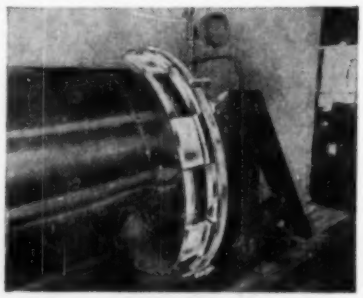
43A Mixers. Constructed of stainless steel the size TWEm with a working capacity of 100 to 175 gal. & jacketed for 125 lb./sq.in. heating or cooling is a typical high production unit. Baker Perkins, Inc.

44L Gaskets. Consolidation creates a major source for all your gasket, packing & allied product requirements be they standard or special. U. S. Gasket Co.—Belmont Packing.

45A Autoclave. Built by Bethlehem Foundry & Machine Co. this reaction vessel, complete with agitator & drive was designed to lower first cost, less maintenance & fewer shutdowns.

61A Plant & Unit Design. Long experience in the fields of conversion, separation, & purification enables Badger Mfg. Co. to successfully design from crude to finished product.

DEVELOPMENTS OF THE MONTH *(Cont.)*



109. Is it necessary for you to open your pressure vessel frequently? If so, Sparkler Manufacturing Co. has a new, easy-to-operate safety cover.

Locked by a series of visible bow-shaped lugs mounted on a third ring, the cover will be standard equipment on all the company's model MCR Retractable Tank vertical plate filters, is available for use on other suitable equipment.

Even in a large diameter tank the ring travels through an arc of only 15-20 degrees, enabling the cover to be opened in seconds without the use of hand tools or power devices.

For information and application details, circle number 109 on Data post card.

110. Application, design and operation of Allen-Sherman-Hoff Co.'s line of slide gate type segregating valves for pneumatic materials handling systems is described in a new illustrated data sheet.

Giving installation instructions as well, the data sheet has dimension drawings and tables, plus illustrations of the various models available.

For more information circle number 110 on Data post card.

(Continued on page 54)

46L Demisters. Higher yields in refinary vacuum towers result from use of Yorkmesh demisters. Clean separation assured. Otto H. York Co., Inc.

47A Pumps. Built to meet the rugged specifications of the chemical industry these units give long, trouble-free service life. New specific data listed in catalog. Aldrich Pump Co.

48L Slime Control. Elimination of slime formation on condenser & heat exchanger waterside surfaces results from chlorination of cooling water. Equipment available from Wallace & Tiernan, Inc.

49A Chemical Plants. No matter what the end purpose for which your plant is intended Lummus Co. will undertake its design, engineering & construction.

50A GLC Anodes. Positive performance of GLC anodes looms large in reduction of cost in production of chlorine & caustic soda. Great Lakes Carbon Corp.

Bronze solder-end valve—See item number 76, page 60.

55A Lever-Lock Door. Unit enables heat exchangers to be opened in 5 seconds resulting in savings. Available in all alloys in diameters 16 through 36 in. Patterson-Kelley Co., Inc.

57A Industrial Dryers. Job-designed & job-guaranteed these dryers are products of years of experience in the field. C. G. Sargent's Sons Corp.

59A Titrator. A dependable, easily operated instrument which makes determinations in 3 to 4 min. Requires no standard solutions. Central Scientific Co.

61A Plant & Unit Design. Long experience in the fields of conversion, separation, & purification enables Badger Mfg. Co. to successfully design from crude to finished product.

63R Conveyor Dryers. Equipment which provides control & flexibility. Many wet-solid materials now handled by the conveyor dryer method. Proctor & Schwartz, Inc.

64L High-Nickel Castings. If you have a castings problem Duraloy Co. invites your consultation with their metallurgist.

65R Aerofins. The new smooth fin is tapered with wide contact base effecting conduction of sufficient heat to make entire fin surface a transfer area. Aerofin Corp.

66L Defoamers. Using Dow Corning Corp. Antifoam A compound & Antifoam A emulsions you can increase production, reduce process time & eliminate waste & fire hazard of boil-overs.

High Pressure Valve—see item number 66, page 58.

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

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Advertisers' Products

IFC	3R	4A	6L	7A	8A	9A	10A	12L
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23A	24A	25A	26L	27A	28L	29A	30A	31A
32A	34A	35A	37A	40A	43A	44L	45A	46L
47A	48L	49A	50A	55A	57A	59A	61A	63R
64L	65R	66L	66R	67R	68L	68BR	69R	70TL
72L	73R	75TL	75BL	75R	76L	77TR	77BR	78L
78TR	78BR	83R	84TL	84BL	85R	532A	IBC	OBC

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

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December, 1955

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Advertisers' Products

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23A	24A	25A	26L	27A	28L	29A	30A	31A
32A	34A	35A	37A	40A	43A	44L	45A	46L
47A	48L	49A	50A	55A	57A	59A	61A	63R
64L	65R	66L	66R	67R	68L	68BR	69R	70TL
72L	73R	75TL	75BL	75R	76L	77TR	77BR	78L
78TR	78BR	83R	84TL	84BL	85R	532A	IBC	OBC

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

December, 1955

products-(Cont.)

66R Pla-Tank. Molded from long-life, resin-bonded glass fibre laminate material resists wide variety of fume & temperatures. Ideal for use in duct systems. Pla-Tank, Inc.

67R Process Equipment. Long experience in repair, rebuilding, & modernization of this equipment has been applied to construction of new units. Assures dependability & economy. Condenser Service & Engineering Co., Inc.

68L Tanks, Filters, Mixers. Regardless of size or type of installation there is an Alsop Engineering Corp. unit to supply your need. Catalog available.

68BR PVC Pipe & Fittings. Solution of corrosion problems with PVC piping is subject of booklet from Tube Turns Plastics, Inc. Outlasts & costs far less than metal systems.

69R Wire Cloth. Anti-corrosive wire cloth fabricated from stainless steel, Monel, Nichrome, meet really tough service conditions. Newark Wire Cloth Co.

70TL Desiccant. Recommended for dehydration of vapor & liquid fed stocks in petrochemical processes, Florite is said to be most economical of granular drying agents. Floridin Co.

72L Filter Media. For use in laboratory or industrial plant this filter material has proven eminently satisfactory. Filtration analysis report available to aid your selection. Eaton-Dikeman Co.

73R Process Equipment. Whatever your need Manning & Lewis Engineering Co. is prepared to design & fabricate the correct unit if you supply performance requirements.

75TL Arched Wafers. This shape has many advantages over flakes or other shapes. Solidification between —60° C. & +200° C. Flakice Corp.

75BL Scientific Research. The modern approach to the solution of technical problems is by scientific research. Services of Foster D. Snell, Inc. are available for this purpose.

75R Comparators. Use of the W. A. Taylor & Co. comparator enables test of pH, chlorine on the spot. Color standards guaranteed.

76L Stirrer. Called Trubore stirrer it features tolerances, is equipped with either Teflon or glass blades & interchangeable precision bearing chuck. Ace Glass Inc.

77TR Sprocket Rim. This newly redesigned adjustable sprocket rim with chain guide makes every valve easily accessible. Easy, quick, solid assembly. Babbitt Steam Specialty Co.

77BR Bubble Caps. A standard reference on bubble caps & risers with complete specification information available from Pressed Steel Co. Dies on hand for all listed styles.

78L Heat & Corrosion Equipment. Design, development, fabrication of tanks, piping, special equipment from corrosion resisting alloy. Misco Fabricators, Inc.

78TR Grinders. Some of the largest capacity production mills for grinding detergents, fertilizers, coals, raw or semi-finished products built by Gruendler Crusher & Pulverizer Co.

78BR Pumps. Units for pumping liquids, gases, slurries without corrosion or contamination. Wavelike motion of steel fingers forces material through tubing. Sigmamotor, Inc.

83R Dust Collectors. Called Multi-Wash, units need no productive floor space. May be installed indoor, outdoor in any available space. Claude B. Schneible Co.

84TL Plastic Pump. The solution to pumping hydrochloric acid is a plastic pump. Has no stuffing box, gasket, or shaft seals. Vanton Pump & Equipment Corp.

84BL Nozzles. Every type of nozzle is contained in the catalog from Spray Engineering Co., available upon request.

85R Evactors. Croll-Reynolds Co., Inc. multi-stage steam jet units maintain industrial vacuum as high as 99.99% of perfect. Effectiveiy used on new & old products & processes.

532A Tower Packing. Intalox saddles & various types of rings in an extremely wide range, & fabricated from ceramics, are available from U. S. Stoneware Co.

IBC Fintubes. Three standard types of fired indirect heaters with gas, oil or combination burners. Guaranteed surface temperature of finned combustion tube to 200° F. above maximum temperature of liquid. Brown Fintube Co.

OBC Lightnin Mixers. Save costs in fluid mixing & forever end stuffing box repacking with an easily replaced rotary seal standard on these units. Mixing Equipment Co., Inc.

bulletins-

1 Cooling Machines. A line of packaged water cooling machines for air conditioning & process refrigeration installations from 5 to 125 h.p. available from Carrier Corp.

2 A new bulletin from Cooper-Bessemer Corp. describes the latest V-angle engine driven compressor widely used in field gathering operations in refineries & petrochemical operations. Also lists technical data on latest development in compressor design for improvement of fuel economy & increasing capacity & range of operation.

3 Research. A complete research, development, & consultation service in the fields of physics, ceramics, metallurgy, chemistry, & mechanics available to industry from Horizons Inc. Illustrated folder covers various fields of interest.

4 Electric Pump Motors. A full color bulletin introduces the latest line of vertical hollow shaft pump motors from ACEC Electric Corp. Units have been developed for driving heavy-duty turbine pumps used by agriculture & industry. Explains design & construction features, shows action drawings. If motor begins to turn in reverse, ratchet locks within 1/72 of a revolution to prevent rotation. Other special features listed.

5 Casting Process. Lebanon Steel Foundry Ceramicast process produces castings to close tolerances without expensive dies. Wood, plastic or metal patterns easily mounted in plaster follow mount. Castings of fine accuracy & exceptional surfaces result in short time.

(Continued on page 56)

DEVELOPMENTS OF THE MONTH (Cont.)

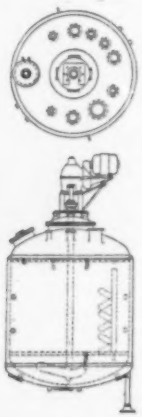
111. With the largest glassed steel vessels to become available as a standard design, Pfaudler's new "R" series reactors also incorporate major design improvements. The large size reactors are the 3000 and 4000 gal. models.

Some of the improvements are: Drive support mounted on a separable center cover; nine nozzles from 3-10 in. in diameter for operating flexibility; manhole located near the side of the vessel for ready accessibility; bottom outlet offset from center of tank permitting agitator to sweep settling material clear of the outlet.

Other new features include: New jacket design providing for two sets of five couplings located on opposite sides of the vessel to permit ready assembly of utility lines; handhole openings for cleaning and inspection of the jacket.

Pfaudler has prepared a full data sheet on its complete new line, including sizes available, all improvements and new features and what they can do in operation, full details of operating temperatures and pressures, and materials that can be handled under all conditions of use.

For more information and data sheets, circle number 111 on Data post card.

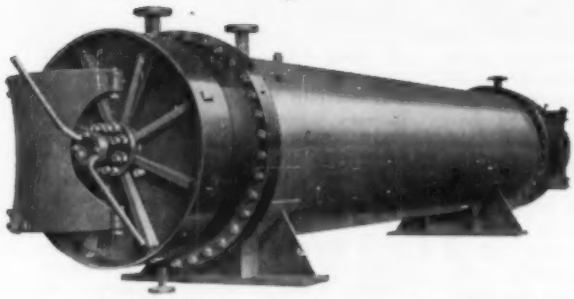


(Continued on page 58)

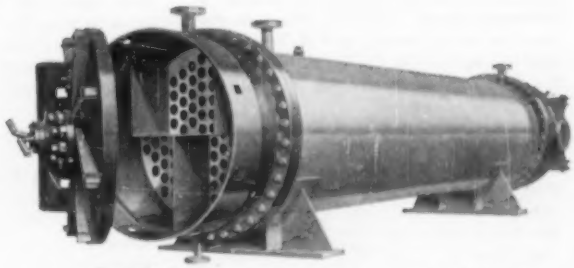
Heat Exchangers Open in 5 Seconds

with new p-k Lever-Lock Door*

Substantial savings seen for processors of high-fouling liquids and others who must clean and inspect heat exchangers regularly.



CLOSED, the Lever-Lock looks like this. A single 1/6th turn of the lever draws back the lock bars.



OPENED manually with an easy pull, the tubes and tube sheet are easily accessible.

Anyone who has had to open a heat exchanger knows how time-consuming and costly it can be. Dozens of bolts must be loosened. Specialized labor is often required. Now these problems can be things of the past. **p-k**'s Lever-Lock Door, available on **p-k** heat exchangers, provides *five-second* access to the unit—and a new approach to exchanger design. The door "unlocks" with a 60° manual turn of a lever. In horizontal position the door then swings open easily. In vertical position, it is lifted by means of a pneumatic cylinder. Either way, it seats itself automatically on a long-life, self-sealing gasket. Other features allow Lever-Lock to be used in a wide range of applications:

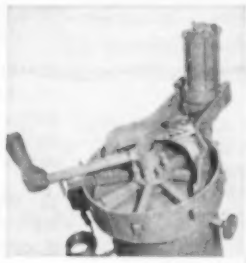
- **Available in all alloys**
- **Pressure range from full vacuum to 300 psi**
- **Temperatures to 400°F. (Special alloys for sub-zero applications)**
- **Mechanical lock available to prevent opening vessel when pressurized**
- **No maintenance other than simple lubrication**
- **Available in diameters from 16" through 36"**

Lever-Lock doors have been used successfully not only on **p-k** heat exchangers, but on **p-k** autoclaves and sterilizers in the chemical, textile, food processing, and rubber manufacturing industries as well. For all of them, and wherever exchangers carry high-fouling liquids or require frequent entry for cleaning and inspection, Lever-Lock doors pay for themselves through savings in time. Heat transfer can be more efficient, too, since you can afford to remove gunk more frequently.

But this is only part of the story. If you see the Lever-Lock as the answer to a perplexing problem in your plant, why not write for *all* the facts, *today?*

The Patterson-Kelley Co., Inc., 1820 Lackawanna Avenue, East Stroudsburg, Pa., and principal cities

*Pat. Pending



1. This autoclave is in vertical position with its Lever-Lock Door equipped with a pneumatic cylinder.

2. To open, operator merely gives lever a 1/6th turn that releases lock bars.

3. Door is lifted in 5 seconds—automatically! An hour or more of work is saved.

Write for new **p-k** Bulletin No. 2030 for full details.

PATTERSON-KELLEY

2575

Offices: 101 Park Avenue, New York 17 • Railway Exchange Building, Chicago 4 • 1700 Walnut Street, Philadelphia 3 • 96-A Huntington Avenue, Boston 16 and other principal cities

bulletins-(Cont.)

6 Portable Pumps. Portable Pump Co. folder covers a portable pump made from stainless steel No. 20 for use with continuous feeds, flows to 25 gal./min., continuous draw-offs & circulation, filtration of small quantities & emptying acid sumps.

7 Reinforced Fiberglass. Strick Plastics Corp. announces availability of Lamicor, a heavy-duty grade reinforced fiberglass for structural use in lengths to 9 ft. long. Suitable for service with most acids & alkalis, has smooth surface, is easy to clean, is translucent or opaque.

8 Glass Insulation. Called Foamglas this cellular stay-dry insulation for piping & equipment is subject of booklet from Pittsburgh Corning Corp. Details on advantages, available shapes, thicknesses for temperatures from —50° to 800° F. A reference for use by engineers, applicators & insulation contractors.

9 Thermal Equipment. Brochure which outlines products & services available from Thermal Research & Engineering Corp. Covers problems of combustion & heat transfer. Describes possibilities of application of high velocity techniques. Photos, diagrams, drawings.

10 Induction Heater. The 30kw induction heater for metal-working industry described in bulletin from Westinghouse Electric Corp. Unit may be used for hardening & heat-treating operations, metal joining, hot heading & forging.

11 Variable Speed Transmissions. Speed-Trol variable speed transmissions are subject of new bulletin from Sterling Electric Motors, Inc. Sections for both layman & engineer discuss inner workings of positive pulley design.

12 Magnets. A complete line of lifting & separation magnets, plus magnet control equipment considered in bulletin from Ohio Electric Mfg. Co. Rectangular field of the Super Magnetomotive unit designed for suspension over head pulley, or in horizontal position over conveyor belt.

14 Shatterproof Plastic Panels. Light-transmitting panels of polyester resin reinforced with fiber glass carry the Underwriters' laboratories label guaranteeing production under rigid inspection. Hooker Electrochemical Co. uses Hetron fire-resistant resin in fabrication.

15 Impervious Graphite. Called Impervite it is used in manufacture of diaphragm & custom-designed valves by Falls Industries. An improved form of resin-impregnated graphite it is light in weight & unaffected by most corrosives. Readily threaded or serrated. For use at temperatures of 340° F. & pressures to 75 lb./sq.in. hydrostatic or 50 lb./sq.in. steam. Bulletin.

16 Steam Supply Units. Both horizontal & vertical Dowtherm vaporizers, for high temperature, low pressure vapor or liquid phase systems for many process heating applications including food, chemical & petroleum processing. Units in sizes from 30,000 to 4,000,000 Btu/hr. output, temperatures to 700° F.

17 Centrifugal Pump. Centri-Chem a type 20 stainless steel centrifugal pump offers corrosion resistance, low cost, sturdy construction, capacities 40 gal./min. with heads to 50 ft. Available from stock. Bulletin from Eco Engineering Co.

18 Stainless Steel Protection Tubes. Conax Corp. speedwell stainless steel protection tubes provide high rate of response. Give maximum protection to thermocouples used in corrosive service. Advantages feature low maintenance, easy conduit connections, complete adjustment of immersion with high pressure & temperature range. Bulletin.

19 Laboratory Equipment. A 76-page catalog from Denver Equipment Co. describes over 146 different items which aid in establishing your laboratory testing needs. Various divisions of their lab discussed. Section on "Minerals and Their Characteristics."

20 Lefax. A loose-leaf pocket-size notebook offering printed data sheets covering every technical field for easy reference. Over 10,000 printed pages available. Lefax.

21. Wall Chart. From Tubular Products Div., Babcock & Wilcox Co. chart showing approximate relation between hardness by various testing systems & tensile strength of carbon & alloy steels.

22 Diaphragm Switch. For accurate sensing of pressure difference from 0 to 45 in. of water between a variable & a reference pressure, with fixed actuation value of 0.5 in., of water. Reference pressure must be air or inert gas; variable may be liquid or gas. Barksdale Valves.

23 Diaphragm Valve. Called Straightway valve offers extra advantages of straight-through flow for handling viscous materials, slurries, sludges, etc. Easy replacement of worn diaphragm. No packing glands, disc holder, or metal-to-metal seat. Grinnell Co., Inc.

24 Corrosion-Resistant Equipment. Illustrated catalog from Haveg Corp. on complete line features new materials of construction & evaluates equipment molded from PVC, epoxy glass & polyester glass. Gives data on resistance to chemicals & heat.

25 Dryers. Available from C. M. Kemp Mfg. Co. 40-page bulletin on line of desiccant type dryer. Explains 26 principal variables of design plus effects of temperature & pressure on size of dryer for specific applications. Flow diagrams & elevation drawings on 56 models. Other data.

26 Temperature Control. Data sheet 866 from Minneapolis-Honeywell Co. on the Ambi-Seat remote bulb controllers. Provide close control with compensation for temperature differences between medium being controlled & air surrounding tubing & bellows.

27 Process Equipment. Conveying systems which eliminate bagging & expensive manual labor in handling cement, talc, other pulverized materials. Also compressors, pumps, coolers & preheaters shown in action. Tables on performance & capacity. Fuller Co.

28 Filters. Rugged, permanent filter membranes plus duty construction are features of ClaRite filters from Croll-Reynolds Engineering Co., Inc. Illustrated bulletin shows three-step operation, gives filter data, other information.

29 Sand Filter. An automatic backwash rapid sand filter a product of Hardinge Co., Inc. discussed in bulletin. Cutaway views, diagrams, features & applications considered.

30 Industrial Radiography. A series of bulletins from High Voltage Engineering Corp. cover the story of the corporation, the model AR two-million volt X-ray generator, the model JR one-million volt generator, the 2-MeV X-rays for supervoltage therapy, & one on particle accelerators. All are well illustrated & cover pertinent data.

31 Valve Selection Chart. Designed for simplified selection of forged needle, bar stock & toggle valves, wall chart available from Hoke, Inc. Provides tubular data on vee & blunt point needle valves, also spring-closing & cam closing toggle valves.

32 Motors & Pumps. 16-page color brochure from New York Air Brake Co. illustrates & describes their vacuum & liquid pumps, air brake equipment & hydraulic motors, controls & pumps. Serves as a quick guide to equipment produced in five manufacturing divisions.

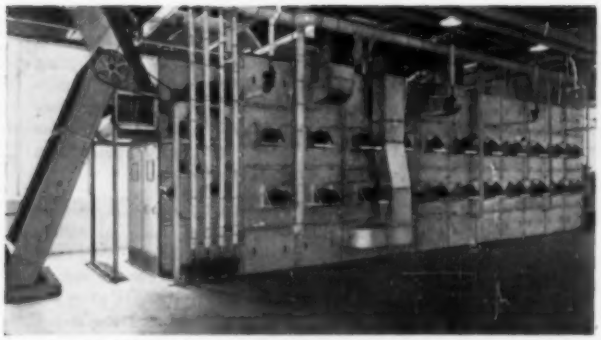
33 Forged Steel Fittings. Newly added to line of Watson-Stillman Fittings Div., H. K. Porter Co., Inc. a 3,000 lb. tab orifice union for instrumentation & process control piping. Eliminates errors in orifice plate identification. Size plainly stamped on tab protruding through slot in end piece of union.

34 Tank Venting Fundamentals. A profusely illustrated booklet from Protectoseal Co. titled "Venting Fundamentals" deals with the principles of venting flammable liquid storage & process tanks for effective operation, fire protection & low-cost maintenance. Second section also available. Contains specification sheets, engineering data, dimensions, etc., for determining proper size & type of equipment.

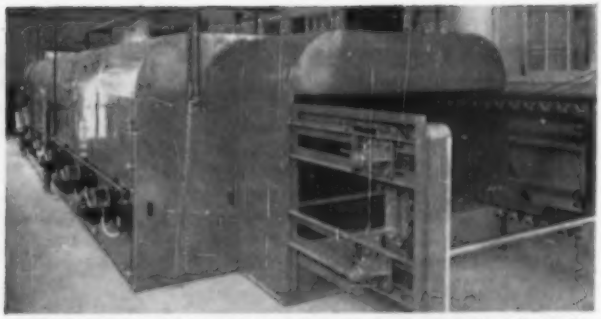
35 Diaphragm Pump. An all-purpose diaphragm pump for feeding chemicals in industry and municipalities is subject of data sheet from Proportioneers, Inc. Advantages include versatility in operation because unit may be powered by electric motor, rotating shaft or gasoline engine; minimum maintenance & long dependable service; "see-thru" pumping head of molded plastic.

36 Faceshield. A clear acetate visor for frontal & side protection against abrasive particle, flying objects, & chemical splashes. Called Skullgard-Faceshield to can be attached to any protective hat. Bulletin from Mine Safety Appliance Co.

(Continued on page 58)



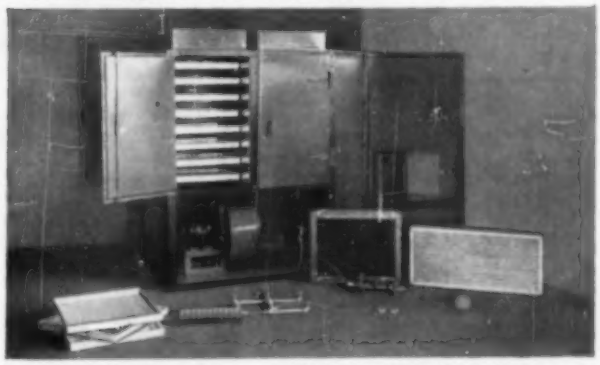
Reclaimed Rubber Dryer installation, showing fan placement. This dryer is an accepted standard in the rubber industry.



Skein Dryer installation in a textile mill. It meets modern demand for economy of operation, for production, and for protecting yarn quality, strength and fine desirable hand.

INDUSTRIAL DRYERS

by SARGENT



A SARGENT Tray Dryer and Air Washer installation in cotton-seed oil processing plant. Shows trays, dirt eliminator, Sylphon Regulator and spray nozzles in foreground.

SARGENT Dryers are job-designed and job-guaranteed. They are the product of our experience gained through many years of designing and building specialized dryers for industry; and through years of trouble-shooting work for a wide variety of industries, in SARGENT'S Drying Research Laboratory.

Wherever a drying process occurs, SARGENT is highly qualified, and has complete facilities, for research, designing, engineering and for building, special drying equipment.

Our fully equipped Drying Research Laboratory is maintained at Graniteville, staffed by highly competent research and engineering personnel. Drying research facilities are available to clients at a nominal charge, to aid in solving the drying problems of almost any industry.

Here are Some of the Products of Industries We Serve:

Abrasives	Nuts and Nut Products
Animal Hair	Paints and Pigments
Building Materials	Paper and Paper Products
Explosives	Plastics
Feedstuffs	Rubber
Fertilizers	(reclaimed, synthetic, natural)
Fruits and Berries	Tobacco
Grains	(leaf, stem, filler)
Kaolin	Textiles
Leather and Hides	(fibre, yarn, cloth)
Inks and Pigments	Vegetables
Metal Parts	Waste Sludges

SARGENT'S PORTABLE LAB DRYER FOR RESEARCH LABORATORIES, PILOT PLANTS, UNIVERSITY LABS

Developed to reproduce every possible condition met in drying for the process industries. COMPLETELY SELF-CONTAINED, needs only service connections when delivered. MOBILE — may be moved to job in plant where needed. Perforated stainless trays (may be had also of wire cloth) are located for updraft, downdraft, cross-draft air circulation in dryer. COMPLETE temperature controls — recording charts, wet and dry bulb thermometers. RECORDS TEMPERATURE CHANGES THROUGHOUT BED OF MATERIAL BEING DRIED. Temperatures to 325° using steam heated air, or to 500° using electricity. WE BELIEVE THIS DRYER IS MORE VERSATILE AND HAS MORE POSITIVE CONTROLS than ever before offered to industry. Available on three plans — direct purchase, rental, or rental-purchase. Ask for Bulletin #204.

C. G. SARGENT'S SONS CORPORATION

Graniteville, SINCE 1852 Massachusetts

PHILADELPHIA 19 — F. E. Wasson, 519 Mullock Road
CINCINNATI 15 — A. L. Merrifield, 730 Bigelow Avenue
CHARLOTTE, N.C. — W. S. Anderson, Carolina Specialty Co.
ATLANTA, GA. — J. R. Angel, Mortgage Guarantee Building
TORONTO, CAN. — Hugh Williams, 47 Colborne Street

equipment-

50 Horizontal Motors. Built to rerated NEMA specifications a line of Uniclosed horizontal motors, with face type mounting brackets for direct connection to driven equipment, provide more horsepower in less space. Available in ratings of 1 to 30 h.p. U. S. Electrical Motors, Inc.

51 Radiation Survey Meter. Nuclear Instrument and Chemical Corp. announces a gun-type radiation survey meter. Its use in determination of amount of radiation received by laboratory workers from experiments with radioisotopes, monitoring shipping containers for excess radiation, remote monitoring purposes, where activities are in order of millicurie amounts present.

52 Steam Traps. Said to be superior in retaining prime under adverse operating conditions is an inverted bucket steam trap from Sarco Co., Inc. High discharge capacities made possible by using large valves operated by Sarco Camlift valve mechanism.

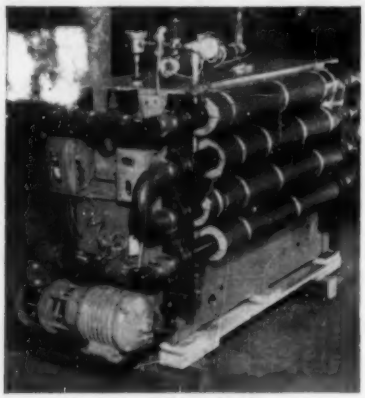
57 Flowmeters. A series of variable flowmeters of simplified design, sturdy construction, & 100% greater visibility of metering tube from Fischer & Porter Co. Called 1700 series Flowrator meter has same features as series 700. One may be substituted for the other without costly pipe changes.

58 Hydraulic Filter Press Closer. An easily installed hydraulic filter press closer called Hydro-Lock converts any mechanically operated filter press to hydraulic operation in minutes. Five standard models from 30 tons with 3 in. stroke to 120 tons with 6 in. stroke. Double pump available.

59 Flow Integrator Unit. A 20-point unit using one sweep pressure generator to simplify & cut cost of readings. Provides separate dial counter readings of as many as 20 total flow measurements on single central station control panel. Fischer & Porter Co.

60 Dust Filters. The Day Co. now equips all housed reverse Hersey type dust filters with a newly designed housing featuring a walk-in access door & two inspection doors.

DEVELOPMENTS OF THE MONTH *(Cont.)*



112 Complete refrigeration units, with pumps of Camac Furacam plastic and heat transfer tubes of Karbate, are available from Carl Buck & Associates, in all sizes to do any solution cooling job.

Unit pictured is for cooling surface acid anodizing solution, other units are built of the proper materials to resist attack by any solution.

If specific temperatures are required, the necessary controls can be furnished with the units.

For full details and capacity sheets, circle number 112 on Data post card.

54 Dry Air Breathers. An inexpensive method of reducing moisture content of atmospheric air entering into oils, chemicals, air, gases or other materials in storage tanks is provided by indicating dry air breathers from McIntire Co. Three stock sizes with capacities 500 to 5,000 gal. tank size, based on conditions of 80° F. & 92% relative humidity entering air.

55 Controlled Volume Pump. Equipped with instrument stroke length a controlled volume pump from Milton Roy Co. Designed for solution of specific low capacity flow control problems. Stroke length adjustable from 0 to 100%.

56 Flooring Materials. A corrosion proof flooring material which resists attack from solvents, alkalies & acids of two to four times better than concrete. Called Coro-Crete material is composed of thermosetting resin liquid, a hardening agent, & an aggregate-type filler. Handles like cement topping, is applicable from ¼ in. to ⅜ in. (per layer), becomes dense in a few hours.

Additions permit periodic lubrication & inspection of gearmotor drive operating reverse jet air pressure blower & screw conveyor discharges. Bulletin 559 filled with facts on unit available.

61 Ball Joints. Of new design ball joints in 8, 10, & 12 in. sizes from Barco Mfg. Co. Flanged & welding end patterns available in three sizes in steel or Bar-Ductile metal. Flanged end joints have flanges 150 or 300 lb. Welding ends suitable for 600 lb./sq.in. steam & temperatures to 1,000° F. Catalog sheets available.

62 Flow Control. An advanced design power-actuated rate of flow control for effective operation of water, waste & industrial plants from Builders-Providence, Inc. Controller comprises Venturi metering section & a pressure recovery section; power-actuated valve mechanism; & pneumatic, hydraulic, or electric positioning control unit. Control accuracy ±3% from 25 to 100% maximum capacity.

63 Pressure Leaf Filter. A self-cleaning pressure leaf filter capable of filtering 12,000 gal./hr. & equipped with sight ports through which individual filter leaves may be inspected, is announced by Hercules Filter Corp. Ports can be dogged down quickly for operation of filter.

64 Adjustable Speed Drive. A precise drive called Ampli-Speed easily to install, handle, & operate from Electric Machinery Mfg. Co. Can be coupled or belted to existing motor to provide control of ±2% for fans, centrifugal pumps, & compressors.

65 Actuator. From Bettis Corp. a self-contained, gas-operated, double-acting actuator for remote operation of plug valves & similar units. Called Robotarm it is a diaphragm separating a large & small air chamber where front chamber is used to act as accumulator. 15 to 100 lb. gas required.

66 High Pressure Valve. Called Micro-Valve this high presure valve from High Pressure Equipment Co., Inc. has a micrometer stem. Perfect for bleeding & metering letdown control. Permits of true micrometer control of all types of testing. Complete range of tubing sizes to & including 9/16 in.

67 Centrifugal Water Chillers. Trane Co. announces their line of CenTraVac centrifugal water chillers is now available for outdoor installation without protective enclosures. Sizes from 50 to 800 ton refrigeration capacity equipped with this feature.

68 Reaction-Distillation Pilot Plant. A data sheet issued by Patterson-Kelley Co. describes the new 15 gal. reaction-distillation pilot plant, a complete & compact, packaged test unit designed for general experimentation in resin manufacture & similar processes. Covers components, also heating & cooling units & explosion-proof instrumentation.

69 Gas Density Balance. Arnold O. Beckman Inc., have added a new instrument, the gas density balance to their line. Measures density of sample gas by unique null balance principle. 95% response obtained in less than a minute. Sensitivity to ½% of full scale; accuracy is ½% of full scale.

70 Refrigerant Condenser. Niagara Blower Co. has developed radical new design evaporative-type refrigerant condenser. Capacities to 240 ton ammonia refrigeration.

71 Fluid Agitators. A complete packaged fluid agitation service developed by Philadelphia Gear Works, Inc. Engineered for lifetime of trouble-free service. Complete engineering service available plus field service in your plant.

72 Gauges. Republic Flow Meters Co. announces line of small-size receivers & draft, pressure & temperature gauges. V-5 series said to give excellent readability & accuracy with scale 5 in. high. Standard draft ranges, pressures to 100 lb./sq.in., temperatures to 1,000° F. may be measured directly. Illustrated bulletin.

(Continued on page 60)

Make determinations in 3 to 4 minutes with the

CENCO coulometric mercaptan titrator

Here's a dependable instrument that provides a rapid, routine method of measuring mercaptans and H_2S in hydro-carbons. It's simple to operate . . . requires no standard solutions . . . measures thiols as low as 100 micrograms. From 15 to 20 consecutive analyses can be run without instrument adjustment. Reaction time registers in tenths of seconds directly on the titrator. Average determination time is 3 to 4 minutes depending upon the amount of mercaptan present.

Overall size 12″ x 12″ x 4½″. Operates from 115 volt, 60 cycle power supply. Licensed under patent rights of Standard Oil Company (Indiana).

No. 20930 Cenco Coulometric Titrator complete, **$549.00.**

Ask for Circular No. 1264.

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CENTRAL SCIENTIFIC CO. OF CANADA, LTD.—TORONTO • MONTREAL • VANCOUVER • OTTAWA

equipment- *(Cont.)*

73 Mass Flowmeter. An extended range mass flow-meter now available from Potter Aeronautical Co. is self-adjusting for specific gravity variations 0.600 to 0.900. Accuracy within ±½% of full-scale for each of five scales used to cover entire range. Components are flow sensing elements, multi-channel frequency converter, electronic self-balancing indicating potentiometer & density detector unit.

74 Oxygen Analyzer. Accurate measurement of oxygen is now an important function in modern plant operations. New bulletin on the model F3 from Arnold O. Beckman, Inc. tells how unit makes measurement directly upon oxygen content of the gas itself. Operating principle illustrated, typical application highlighted, & technical data is given.

75 Variable Speed Pulley. For limited space application a new ¼ hp. variable speed pulley. Speed ratios up to 2:1. Maximum bore is ⅝ in. with keyway. May be mounted with belt take-off close to motor and/or reversed. Lovejoy Flexible Coupling Co.

76 Valves. Five bronze solder-end valves added to line of Lunkenheimer Co. Three gate valves—rising stem with double- or solid-wedge discs, non-rising with single-wedge disc. All rated 125 lb. steam pressure & 200 lb. water, oil, or gas. Also a bronze swing check valve & a non-metallic disc globe valve.

77 Butterfly Valves. The first half of what is said to be the most complete catalog of butterfly valves ever compiled is available in loose-leaf form from S. Morgan Smith Co. Includes section on basic engineering data complete enough to permit user accurately to size nee ed valves. Line ranges from 15 to 300 lb. Describes each valve with specifications, drawings, & dimensions, in each given pressure rating.

78 Thermocouple Covers. Marketing of the new Hi-Temp thermocouple with platinum 30% rhodium—platinum 6% rhodium calibration, capable of measuring temperatures to 1,800° C. announced by Thermo Electric Co., Inc.

79 Slide Rule. C. J. Major Co. announces the availability of a liquid flow slide rule for quick, accurate calculations of pressure drop in pipe lines & tubes. Automatically indicates where turbulent or streamline flow exists in a given problem.

materials-

90 Molybdenum Catalysts. Climax Molybdenum Co. reports 600% increase in use of molybdenum in catalysts over past two years in booklet "Molybdenum Catalysts for Industrial Processes." Sections on reactions using molybdenum catalysts, oxidation, hydrogenation, dehydrogenation, chlorination, etc., together with references & a list of other Climax publications.

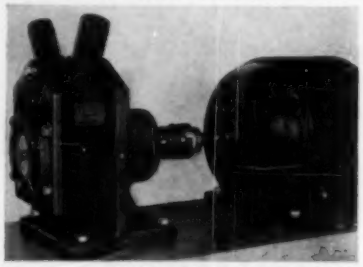
91 Boron Handbook. A "Handbook on Boron Carbide and Elemental Boron" has been made available by Norton Co. 16 pages of technical information on materials made by them for use in field of atomic energy.

92 Plasticizer. Called Esterflex B-1 a new generic type of plasticizer from Swift & Co. It is for general purpose use & is the first of a series produced. Chemical structure is said to be unique. Contains both polar & non-polar groups. Particularly adapted for PVC compounds.

93 Plastisol Coatings. Data sheet from Quelcor, Inc. details material manufactured from fine particle size PVC resins to which are added specific plasticizers. Finished product is heat fused onto the metal base & cured to a smooth, tough, resilient surface.

94 Silica Gel. Titled "Dehydration of Air and Gas with Davison Silica Gel," technical bulletin from Davison Chemical Co. Reports results of research in the field.

DEVELOPMENTS OF THE MONTH *(Cont.)*



113 Pumps which eliminate the need for stuffing boxes or mechanical seals, and in which the fluid passing through never comes in contact with metal, are the "flex-i-liner" pumps of Vanton Pump & Equipment's new series.

Adaptable to almost any fluid or slurry, no matter how corrosive or abrasive, the pump comes in many sizes, with a wide variety of materials of construction.

A new catalog, fully illustrated, is now available on these pumps.

For full information circle number 113 on Data post card.

95 Concrete Protection. Announced by Ceilcote Co., Inc. the successful protection of trenches, tank bases & other concrete surfaces against corrosion from perchlorethylene & hydrochloric acid spillage. It is a combination of three Ceilcote materials using shale acid-proof brick, Corobond resin cement & Ceilcrete "B" a plastic-base thermosetting coating.

96 Fatty Acids. Revised brochure from Emery Industries, Inc. contains up-to-date specifications of entire line of products including stearic acids, oleic acids, special fatty acids, & others.

97 Clarifiers & Thickeners. Infilco, Inc. manufacturers of water & waste treating equipment have issued a bulletin on their clarifiers & thickeners. Questions on design requirements for a wide range of capacities & solids removal loads are answered.

98 Foaming Agent. Non-ionic surface active agent polyethylene glycol 600 Mono Oleate has been found efficient for use as a foaming agent in polyurethane rigid foams. Data & sample available. Glyco Products Co., Inc.

99 Silicone Mold Lubricants. A comprehensive study of silicone mold lubricants for the rubber industry has been prepared by Dow Corning Corp. Properties & performance of leading agents discussed; application methods described; suggested formulas for problem situations.

100 Protective Coatings. Corrosion resistance may be built into your product by use of Amercoat coatings to protect structural steel, tank exteriors & interiors, pumps, motors, & other units. Bulletin reviews available coatings & their applications.

101 Hydraulic Tables. Aldrich Pump Co. announces publication of bulletin No. 20, "Handbook of Hydraulic Tables and other Engineering Data." A reference work for use by engineers interested in pumping & piping problems.

102 Chemicals Catalog. A general products catalog containing over 350 basic industrial, agricultural & pharmaceutical chemicals is announced by Dow Chemical Co. Property information presented in tabular form together with general use data. Index lists each item by catalog name & synonym. Included are plastics, coating materials, magnesium, titanium, amino acids, & many others.

103 Waxes, Oils & Greases. From M. W. Kellogg Co. a 16-page booklet on chemical structure, specifications, properties, applications & description of a new group of fluorocarbon oils, waxes, & greases for industrial uses.

104 Neoprene Notebook. No. 66 in the series from the Elastomers Div. of Du Pont Co. Considers resistance to natural aging, fighting the hot box, trial by fire, flexible idlers, waterproof flashlight, & other subjects.

105 Adipic Acid. Technical bulletin I-12 from Allied Chemical & Dye Corp. covers six basic reactions of the carboxyl group & eleven of the Alpha methylene group. Suggests uses & gives 45 literature references.

106 Coating Resins. A revised booklet from Barrett Div., Allied Chemical & Dye Corp. is devoted to description of Plaskon coating resins for paints, varnishes, lacquers & the like. Presents by charts & short descriptions complete characteristics for coating resins such as alkyds, silicone-alkyds, ureas, melamines, with typical applications for each.

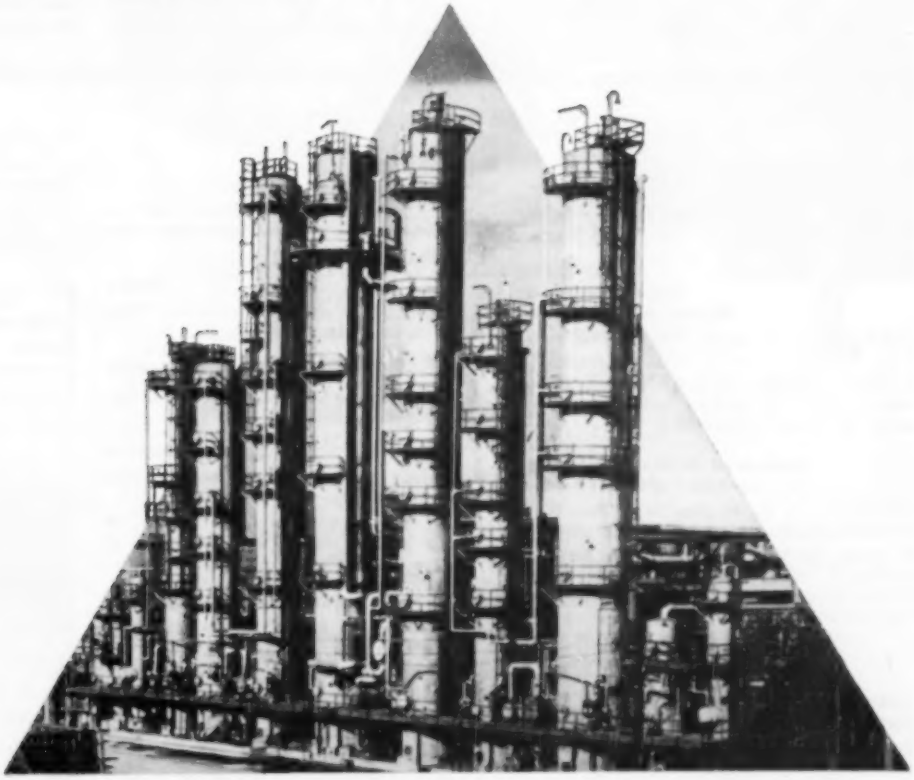
107 Solvent Recovery. Carbide and Carbon Chemicals Co. new 36-page booklet on the Columbia activated carbon system of solvent recovery gives technical data on activated carbon, & describes efficiency & economy of recovery of solvent vapors. Complete recovery plants designed & supplied for specific conditions. Capacities 50 to over 100,000 gal /day of solvent.

Experienced in Plant and Unit Design from Crude to Finished Product

Conversion * Separation

mBc

Purification



* Name the separation step and we can match it up with direct or parallel experience. Distillation, Liquid Extraction, Absorption, Crystallization are typical of the operations which our engineers know thoroughly and for which they have designed many a plant and unit.

BADGER MANUFACTURING COMPANY

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FUTURE MEETINGS and Symposia of the Institute

■ **LOS ANGELES, CALIF.**

Feb. 26-29, 1956. Statler Hotel.

Process Economics

How to decide whether to build, replace, or abandon a processing facility, including techniques for analysis and control of budgets. Papers will cover appropriation requesting, alternatives of capitalized cost, effect of thoroughness and accuracy in cost estimation for economic evaluations, effect of interest rate return on expenditures, criteria for abandonment and availability of capital.

The Study and Control of Fast Reactions

The fundamentals and the technology of freezing of chemical equilibria are expected to be considered. Papers on a new technique for investigating gas phase reactions, use of phase lag measurements, a new nitrogen process, and use of fast reaction concept in combustion processes.

Supervision of Engineering and Scientific Personnel

The general characteristics of the professional employee which create special problems of supervision. This will be a panel discussion.

Air Pollution

Tools and techniques for cleaning of effluent gases to minimize contamination of the air. Factors affecting electrical precipitation, tracers, the soil, adsorption and absorption, and a survey of cleaning techniques.

ABC's of Machine Computation

Designed for those people who lack specific knowledge of automatic computation. Digital computers will be reviewed, and their use explained. The same will be done regarding an electronic differential analyzer. Both small and large computer installations will be described by industrial people who are currently using them. The training of engineers in the use of computers will be discussed by an educator. A field trip is planned to enable viewing and discussion of a nearby computer installation.

Note: The Author Information column will appear quarterly in the January, April, July and October issues.

MEETINGS **SYMPOSIA**

■ **NEW ORLEANS, LA.**

May 6-9, 1956. Roosevelt Hotel.

TECHNICAL PROGRAM CHAIRMAN: H. E. O'Connell, Ethyl Corp., Box 341, Baton Rouge, La.

Effective Industrial Financial Aid to Colleges

CHAIRMAN: K. O. Beatty, No. Carolina State Coll., Raleigh.

A Sunday afternoon panel discussion to try to resolve means of implementing our growing needs for trained personnel.

Fundamental Mechanism in Boiling, Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Dev. Co., Emeryville, Calif.

To cover the large middle ground between studies of nucleation kinetics and empirical studie. of over-all boiling and condensation heat transfer rates.

Foreign Chemical Developments & their Effect on U. S. Chemical Industry

CHAIRMAN: C. W. Humphreys, Shell Chem. Corp. 50 W. 50th St., New York, N. Y.

The effect of foreign competition, both commercial and technological, upon the U. S. chemical industry.

Liquid Metals

CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., N. Y. 17, N. Y.

The fields in which liquid metals have merit and the methods of utilizing them, with particular emphasis on sodium.

Fluid Mechanics

CHAIRMAN: Harold Johnson, Dept. of Mech. Eng., U. of Calif., Berkeley.

Deadline—January 6, 1956

■ **PITTSBURGH, PA.**

Sept. 9-12, 1956. Wm. Penn Hotel.

TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Purdue U., Lafayette, Ind.

Distillation Computation Methods

CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

Operations Research

CHAIRMAN: George D. Creelman, Creelman Assoc., 2245 Harcourt Dr., Cleve., O.

Case studies showing a wide variety of methods and techniques in applications of operations research in chemical engineering.

Explosions in Chemical Engineering

CHAIRMAN: G. H. Damon, 366 Ashland Ave., Pittsburgh 28, Pa.

Symposium on gas and dust explosions.

Deadline—May 11, 1956

■ **ANNUAL—BOSTON, MASS.**

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

SYMPOSIA BEING PLANNED

Reader inquiries invited.

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Filtration

CHAIRMAN: F. M. Tiller, U. of Houston, Cullen Boulevard, Houston 4, Tex.

The flow of liquids through compressible media, with experimental and theoretical papers.

■ **TERRE HAUTE, IND.**

April 21, 1956. Rose Polytechnic Institute.

1-day meeting on Bio-Engineering sponsored by the Terre Haute Section, A.I.Ch.E.

CHAIRMEN: C. W. Smith and R. A. Shurter. Contact Mr. Shurter at Commercial Solvents Corp., Terre Haute, Ind.

LOCAL SECTION future meetings

■ **PITTSBURGH**

Jan. 4, 1956.

Younger member activity to be planned.

■ **NEW HAVEN**

Jan. 17, 1956.

Warren C. Schreiner, "Design & Performance of Perforated Tray Bubble Towers."

■ **NEW YORK**

Jan. 17, 1956.

Fred Schurig, "Packed Towers & Tower Packing," (Panel Discussion).

■ **RHODE ISLAND**

Jan. 19, 1946.

J. W. Westfall and J. Katz, "So You Want to Start a Business."

INDUSTRIAL NEWS

A contract for the construction of a 40,000-ton Butadiene plant has been made between Firestone Tire & Rubber and Catalytic Construction Co. □

Construction has started on Pennsalt's sizable new Calvert City, Ky., unit for the electrolytic production of potassium hydroxide. The continuous process will employ DeNora mercury cells and will produce only liquid chemical at first. □

Nearing completion is 35 million lbs./yr. expansion of the oil furnace carbon blacks of Cabot Carbon Co. of Canada, Ltd., Sarnia, Ontario. □

A three-point expansion program at Ansul Chemical Co., Marinette, Wisc., is fully underway. Nearing completion is a plant for the manufacture of sodium bisulfate, a niacin plant is expected to go on stream about January 1, 1956, and a $100,000 addition to the company's fire-fighting equipment production is in the final planning stages. □

Vinyl acetate capacity at DuPont's Niagara Falls, N. Y., electrochemicals plant is being expanded to the extent of $2 million dollars of additional capacity. □

A 14,000 bbl./day Ultraformer is being engineered and constructed for the Standard Oil Company (Indiana) by The Ralph M. Parsons Co., Los Angeles. Unit goes up at the company's Whiting, Ind., refinery. □

Rockwell Mfg. Co., Pittsburgh, will soon start work on a new $1 million assembly and repair plant at Porterville, Calif. Plant will assemble the company's Rockwell meter and valve products, and Rockwell-built Delta power tools. □

A battery of sixteen 30,000 gal. high-pressure ammonia storage tanks, forming one of the largest ammonia storage terminals in the U. S., has just been placed in operation by Mid-South Chemical Corp., Harlingen, Tex. Situated at the Port of Harlingen, the terminal was built by Edward S. Nelson, Ltd., Clarksdale, Miss. □

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- Faster, More Uniform Drying
- Flexibility of Operation
- Guaranteed Product Quality

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AT NATIONAL YEAST COMPANY

Yeast requires sensitive drying methods. This Proctor & Schwartz installation at National Yeast Company maintains the uniform quality, color, and viability of the yeast at considerably increased drying rates.

Proctor equipment provides the control and flexibility essential to profitable drying performance. Many wet-solid materials heretofore unsuited to conveyor drying can now be handled with speed and efficiency. And, as with all Proctor equipment, guarantee *is in terms of finished product produced.*

WRITE FOR BULLETIN # 390

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- Truck Dryers
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Manufacturers of Industrial Drying Equipment and Textile Machinery

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35% NICKEL

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15% CHROMIUM

Furnace Castings

Here are two good examples of our work in high-nickel castings!

These are in the Duraloy HT group calling for Ni 33.37 percent. We've gone as high as 68% nickel on some castings where extremely high temperatures and very severe corrosive conditions had to be resisted. The important factor concerning castings for exceptionally high temperatures is that they must retain their structural form under load.

Knowing just how much nickel to put in and how much chromium and other alloying elements depends to a large extent on experience . . . and it is experience that we can offer you for the castings you need. We've been producing static castings since 1922 and centrifugal castings since 1933, being among the pioneer founders in each class.

If you would care to have our metallurgist study your casting problem, we shall be glad to have you call upon us for the service.

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DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.
CHICAGO OFFICE: 332 South Michigan Avenue

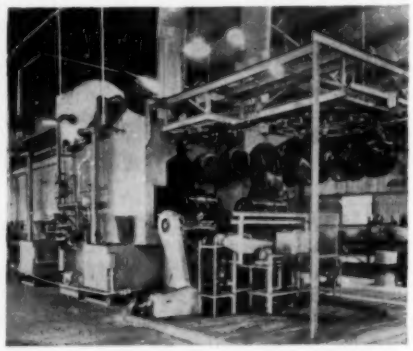
INDUSTRIAL NEWS

Koppers Co. buys Turner & Haws Engineering Co., West Roxbury, Mass., producers of a special line of filters for cleaning industrial air or gas. □

$500,000, 30,000 sq. ft., two-story building will be constructed in Cleveland as the major part of the expansion underway at Arthur G. McKee & Co., Cleveland. □

Now in operation is U.S. Rubber's new Gastonia, N. C., latex processing plant. Third plant of its type built by Naugatuck Chemical Division, the installation is a "pipe-line" operation from storage through processing to loading for shipment. □

Two adjacent Los Angeles manufacturing plants have been bought by Ladish Co., Cudahy, Wisc. Ladish makes drop forgings, pipe fittings and rolled rings. □



Principle feature of Jones & Laughlin's new steel drum and container plant at Port Arthur, Tex., is its nearly completely automatic production line. Here, the ovens are baking the exterior coatings on drums. □

Wide expansion program of General Aniline's Antara Chemicals Division in the liquid detergent field is to be highlighted by construction of a new plant in Calvert City, Ky., installation of additional facilities at the company's Linden, N. J., plant, and leasing of large storage tank facilities in Los Angeles and Alameda, Calif. □

New allyl chloride and chlorohydrins plant at Norco, La., has just been opened by Shell Chemical. This makes Shell the country's largest supplier of glycerine. Further expansion is planned. □

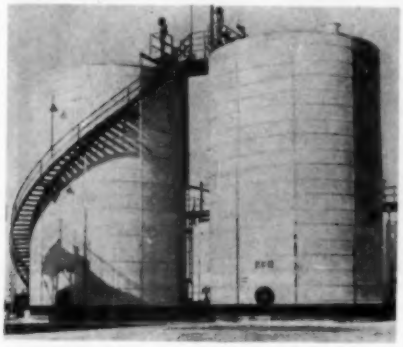
New barium carbonate plant has been opened by Sherwin-Williams at Coffeyville, Kansas. Set-up in conjunction with the firm's 80-acre lithopone, leaded zinc, and zinc sulphate facilities, the new plant will initially produce about 7500 tons/yr. of barium carbonate, is expected to expand soon. □

Increased production of polyethylene bags and drum liners will be the result of the shift of all Bemis Bag's plastic bag operations to a new building in Terra Haute, Ind. Plant will be operated by Flexible Package Co., Chicago, a wholly-owned subsidiary of Bemis. □

A $1 million chemical processing plant will be built at Rockwood, Mich., by Hagan Corp. The new plant will process various Calgon water conditioning products, for industrial and consumer use. □

Second UOP Platforming unit has gone on stream at Atlas Processing Co.'s Shreveport, La., refinery. Engineered, designed and licensed by Universal Oil Products, the unit has a capacity of 3,500 bbls./day. □

Carbide's refined sorbic acid is now being produced in a new unit at South Charleston, W. Va. Capacity is 1 million pounds/yr. □



The phenol-from-cumene process is being used at Standard Oil of California's new Richmond, Calif., plant. For storing the phenol, Standard has turned to Hortonclad tanks produced by Chicago Bridge & Iron, in order to protect the purity of the phenol. □

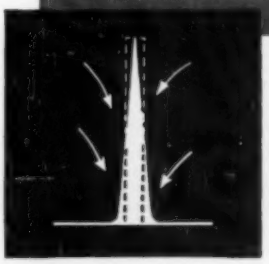
Work has been completed on the $22 million "terylene" (Dacron) manufacturing plant of Canadian Industries (1954) Ltd. west of Kingston, Ontario. Designed and constructed by a subsidiary of the H. K. Ferguson Co., Cleveland, the plant includes five-story polymer and spinning buildings, an analytical lab, a sewage disposal plant and a boiler house. □

New octyl alcohol plant of Texas Eastman, Division of Eastman Kodak, at Longview, Texas, is now in full production. The new product will be marketed as 2-ethylisohexanol since this isomer is present in high concentration. □

Goodyear is about ready to start work on the $3.5 million expansion of its Chemigum and resin plant at Akron, O. Entire project should be completed by next August. □

Even More Surface
per sq. ft. of face area
Even Less
Air Friction

with the New AEROFIN Type B
Smooth-Fin Heat Exchangers



Tapered Fin

The new smooth fin is tapered, with a wide contact base which conducts sufficient heat to make the entire fin effective transfer surface. It is no longer necessary to crimp the fin to provide the required contact area.

Aerofin is sold only by manufacturers of fan-system apparatus. List on request.

By eliminating the air resistance and turbulence caused by the fin corrugations in the old-type coils, it is now possible to use almost twice as many fins per inch with no increase in air friction.

The resulting increase in capacity is obvious. As a consequence, these new coils offer:

Greater capacity per square foot of face area

Lower airway resistance — less power needed to deliver the required C. F. M.

Smaller face area, due to the practical use of higher air velocities

Fewer rows of tubes for a given B.T.U. transfer in a given area

Less weight — easier handling

Better drainage of condensation from water coils; improved venting and drainage for heating coils

Compact, sturdy design

Standardized encased units arranged for quick, economical installation

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Dow Corning Antifoam A* Compound and Antifoam A emulsions are the most efficient and versatile foam killers ever developed. Thousands of successful applications prove they increase productive capacity, reduce processing time, eliminate the waste and fire hazard of boil-overs. And all three, Antifoam A Compound[1]—Antifoam A Emulsion—Antifoam AF Emulsion[2], are effective at low concentrations. For example:

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. . . Antifoam A Compound kills foam in

35,000 lb
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textile sizing

. . . Antifoam AF Emulsion kills foam in

2,075 lb
chocolate syrup

[1] Permissible in food processing at concentrations up to 10 ppm.
[2] Permissible in food processing at concentrations up to 32 ppm.

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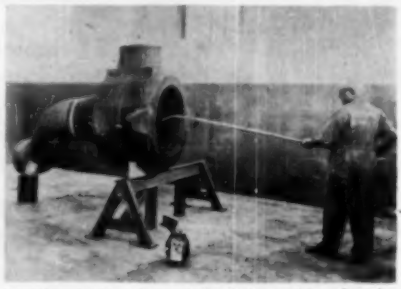
RADIOACTIVE COBALT TEST WELDS

A new, accurate and convenient method for testing welds right in the plant.

To avoid both the cost and problem of shipping parts outside the plant for X-ray testing of welds, or the necessity to have outside testers come into the plant, National Supply Co., at its Toledo, O., plant, has turned to the use of cobalt-60.

Used to test welds with walls as thick as 2½ inches, and on large and complicated alloy steel castings as well as piping, valves, etc., the cobalt-60 method has been found highly satisfactory by National Supply's engineers, particu-

Cobalt-60, obtained from AEC through Tracerlab, was chosen since it offers a source of gamma rays equivalent to that of radium costing more than 30 times as much. Despite its much shorter half-life when compared to radium, even with several replacements the cost is still a fraction of that of radium.

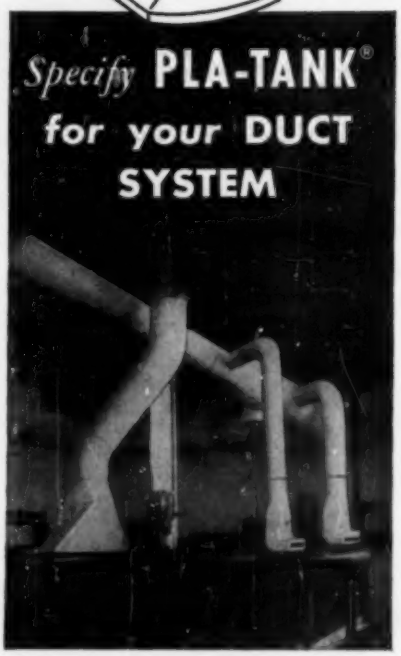


Handler places the cobalt-60 in position for the test. White tape is film in place at point of weld.

In the testing process, X-ray film is wrapped around the outside of the weld, metal numbers are taped at several points for location identification. Penetrometers, small pieces of steel some 2% of the weld-thickness with holes through them, are also taped on for comparison to dark spots that could mean defects in the weld. The film is covered with opaque paper to protect it from visible light, and the cobalt-60, a piece ⅛" square in a stainless steel capsule, is put into position to emit its gamma rays through the weld. Time in position varies from 20 minutes to 8 hours depending on the conditions of test.

The problem of protecting the handlers involves thorough care, including use of the material in a room with 18" thick concrete walls, handling with a 7-ft. aluminum rod, magnetized at one end to hold the stainless steel capsule containing the cobalt-60, and every other possible precaution and exposure warning device.

FROM RAINCAP TO HOOD



Illustrated above is part of a new PLA-TANK Duct System which is typical of dozens being installed for fume exhausts in plating rooms, maintenance shops and chemical processing plants. PLA-TANK was chosen for the entire system from hoods to raincaps on the outside stacks.

Included in the system (in addition to hoods, ducts, stacks and caps) are molded PLA-TANK fan housings and propeller-type fan blades. *Everything that contacts the fumes is molded of chemical-resistant PLA-TANK.*

PLA-TANK, molded from long-life, resin-bonded glass fibre laminate is resistant to a wide variety of fumes and temperatures. It is lightweight, easy to install, competitively priced.

PLA-TANK can be the answer to your duct system problem. Let us help you the modern way — with PLA-TANK.

First in the field — and still the leader

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DIVISION OF

THE Chemical CORPORATION

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ULTRA-HIGH TEMPERATURE CHLORINATION

New furnace goes on-stream at Metal Chlorides Corp., operates above 4000° F.

Designed for use in rapidly expanding field of metal chlorination, a new ultra high temperature chlorinating furnace of Metal Chlorides Corporation, Middleport, N. Y., has been operating well above 4,000 degrees F. Built for the continuous halogenation of metal carbides, oxides, ores or slags, the furnace has produced at tonnage rates at temperatures close to or beyond the sublimation or boiling points of many raw materials currently used for making titanium, silicon, or boron chlorides.

The furnace can stabilize temperatures at any level, maintain endothermic reactions, overcome the heat losses suffered by some other furnaces that must rely upon exothermic heat to maintain chlorination reactions, and provide maximum temperatures at the point where chlorine comes in contact with the bed of feed material. Residual materials such as iron or hot slag can be withdrawn from the furnace as they accumulate. Feed materials can be balanced against the rate of chlorine flow to provide a fairly constant depth of bed in the hot zone. The charge can be introduced or emptied and the chlorine started or stopped without clogging the furnace.

Fuel costs for the test furnace—a small-sized commercial unit—have averaged $0.15 per hour.

A rapid reaction is obtained due to the very high temperatures employed for the chlorination. The complex compounds that result from reactions in the 800-1,000° C. range which is generally employed for production of titanium or silicon tetrachloride in other furnaces, may be expected to be reduced to relatively simple compounds at the near-dissociation temperatures of 2200-2400° C. employed in the Metal Chlorides furnace.

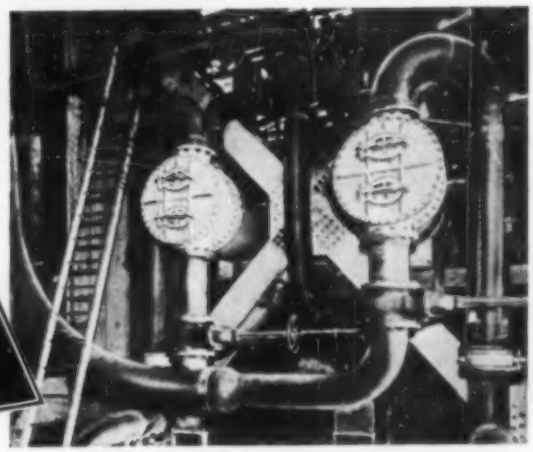
The Company is now preparing to build standard furnaces with four times the capacity of the initial unit. □

Several million dollars will go into modernization of Westvaco's chlorine facilities at South Charleston, W. Va. Westvaco, a Division of Food Machinery and Chemical, will replace its present Vorce and Nelson cell production with the latest developments in chlorine producing facilities. □

Geon polyvinyl plastic materials will be produced in B. F. Goodrich Canada's proposed $3.5 million plant near Niagara Falls, Ontario. □

CONSECO EQUIPMENT

performs better costs less to maintain



Conseco Condensate Coolers for hydrogen cooling installation in large utility. Note quick-opening doors for tube sheet inspection. Units are two-pass channel type. Courtesy Public Service Electric and Gas Co.

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. . . of practically all other makes of condensers, heat exchangers, pressure vessels, steam jet air ejectors, and other power and processing equipment. This experience in repairing, rebuilding, and modernization is applied by our manufacturing division in the design and production of Conseco Equipment.

WE KNOW, as is possible in no other way, where troubles develop—and Conseco Engineering forestalls them. Only Conseco offers you this advantage, and the dependability and economy which it assures. State your requirements, and we'll send you informative bulletins.

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Regardless of the size or type of your installation, whatever your process may be, there's an Alsop Filter, Mixer, and Storage and Mixing Tank to "fit your job," you can be sure of getting from Alsop the right unit properly applied—you can depend on Alsop proved performance features. Alsop Filters, Mixers, and Tanks are available in a complete range of sizes and capacities, and Alsop Equipment is custom fitted to your application by engineers who have thorough experience in Filtration and Agitation. For full information, recommendations, and quotations write Alsop Engineering Corporation, 1010 Gold Street, Milldale, Connecticut.

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INDUSTRY-TAUGHT COLLEGE COURSE

Rensselaer Polytechnic Institute, feeling need for practical view on chemical engineering called on Northeastern New York Section of A.I.Ch.E. for practicing engineers to teach credit course.

Supplying the technically trained men for the country's industry is a task colleges have set for themselves. But relations between colleges and industry are too often marked by a polite silence, a "hands-off" attitude.

To combat this, to fill the need of the students for the industry-view, a plan was devised by Washington University, St. Louis, and Monsanto Chemical Co. (joined later by other companies) where engineers from Monsanto taught a credit course relating primarily to plant design. This plan, explained in detail by one of its originators, W. T. Nichols, in *CEP*, April, 1952, came to be called the "St. Louis Plan."

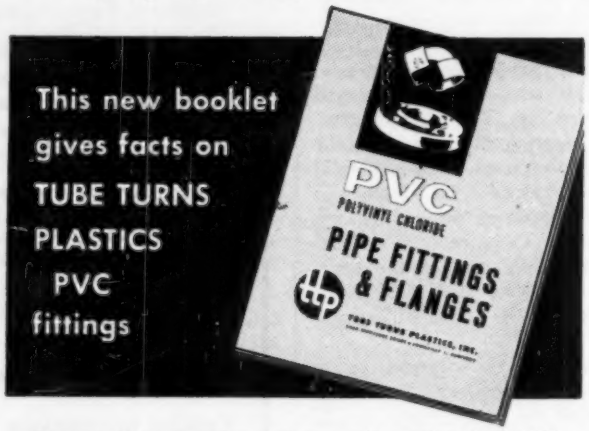
Now RPI, feeling a similar need, has adopted a similar solution with the help of Northeastern A.I.Ch.E. Under the sponsorship of B. V. Coplan, practicing engineers of the Section undertook to furnish materials for the Plant Design course at RPI—a course for the final semester.

This was in 1953. So successful has the course proven, so much good has been done for both students, college, and industry, that it was immediately repeated in the Spring of 1954. Some changes were indicated, since the students had pointed out that some of the material required in their design work had not been presented until late in the term.

The 1954 experience was even more successful, and it appeared that the RPI Seminar Course, given for credit, was becoming an established part of the chemical engineering curriculum at RPI. At the end of the 1954 term, the students were asked to answer questions and make suggestions as to how the schedule might be improved. The replies indicated a desire for more emphasis on orientation, since employment interviews are taken at the start of the last semester. Accordingly, the schedule shown in the table was prepared for the 1955 course.

While departing from its original concept as a practical aid in the Plant Design Course, the RPI Seminar Course has grown in stature as a worthwhile enterprise. The students have benefited, through exposure to a variety of highly expert technical instruction. RPI has benefited through amplification of their

Stop piping corrosion!



You can solve corrosion problems with unplasticized PVC piping—outlasts and costs far less than metal systems for handling many types of corrosive materials. New booklet gives properties and applications of PVC systems, describes PVC pipe fittings and flanges made by Tube Turns Plastics, Inc., the only source for injection molded PVC products. Produced by the exclusive Hendry process, these PVC fittings are considerably stronger than fittings made by conventional processes. Write Tube Turns Plastics, Inc., Dept. PB-12, 2929 Magazine Street, Louisville 11, Kentucky.

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curriculum by a number of practicing chemical engineers. And the Institute has benefited through planning and executing an activity which has brought the members of the local section more closely together.

The lesson learned from this is that the principle of the college seminar course is sound, and can be profitably modified and applied by smaller as well as larger sections of the Institute.

1955 RPI SEMINAR COURSE

1. Introduction
2. The Chemical Engineer in Manufacturing
3. The Chemical Engineer in Development
4. The Chemical Engineer in Marketing
5. The Chemical Engineer and Labor Relations
6. Health and Safety*
7. Water Management and Waste Disposal*
8. Concept and Development of an Industrial Project*
9. Construction Costs and Estimates*
10. Role of the Project Engineer
11. Selection of Equipment
12. Corrosion
13. Instrumentation

* Subjects from original course.

—B. I. MacDonald, Jr.

A.A.A.S. FELLOWSHIP FOR A.I.Ch.E. ENGINEERS

New honor for A.I.Ch.E. Members is Fellowship in the American Association for the Advancement of Science.

Fellowship status in A.A.A.S. is limited to those who have contributed to the advancement of science by publication of original research beyond the doctoral thesis, or in some other significant manner, such as advanced teaching. Normally selection is an individual matter. But a select group of organizations of scientific and engineering men are considered so exacting in their membership standards that high grades of membership are evidence *per se* of outstanding research qualifications.

A.I.Ch.E. is now one of these special organizations. Any A.I.Ch.E. Member will automatically become a Fellow of A.A.A.S. immediately upon joining that body.

An applicant for membership in A.A.A.S. need simply state he is a Member of A.I.Ch.E., say when he was granted Member status, and he will be made a Fellow of A.A.A.S. at once, with the Fellowship privileges of eligibility for officership in A.A.A.S., eligibility for Board membership, Section Committee membership, and A.A.A.S. Council membership.

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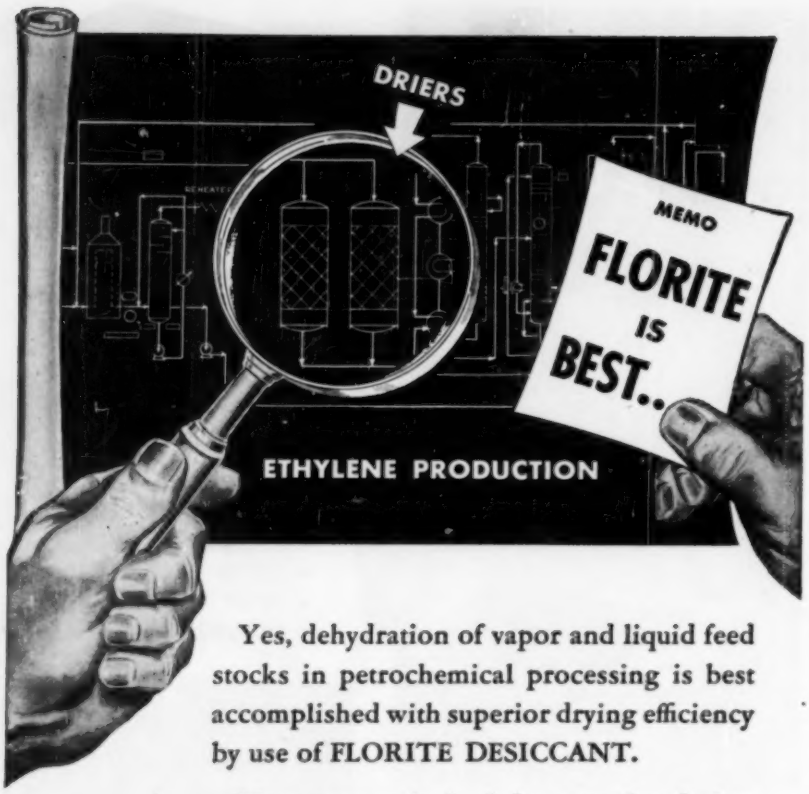

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F. J. VAN ANTWERPEN, *Secretary*
American Institute of Chemical Engineers
25 W. 45th St., New York 36, New York

Dear Sir: Please send me information regarding membership requirements. 12-55

Name: _____ Age: ____
Address: _____
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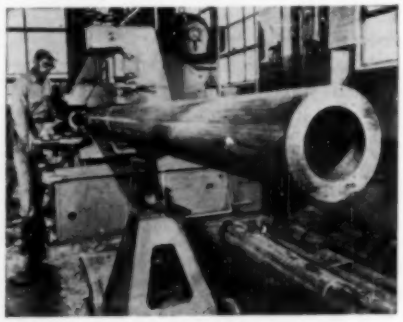
REFERENCE SERVICE FOR INSTRUMENT RESEARCH

Government sets up new system to aid scientists.

An instrumentation reference service has been established at the National Bureau of Standards as a means of providing Government laboratories with more complete access to existing information on measuring instruments, controls, and data handling devices. Devised and maintained by the Bureau's Office of Basic Instrumentation, the new service will increase the effectiveness of scientists working on Government research, help them to arrive more quickly at the frontier of a particular area of investigation. Economies are also anticipated through elimination of unnecessary duplicate effort.

Although the Bureau's service is presently limited to Government agencies and their contractors, the techniques can be applied by anyone having similar indexing problems. Basic innovations: Improved system for indexing sources of information; inexpensive hand-operated indexing equipment newly designed and constructed. The system is based on the newer concept of indexing which at NBS is referred to as the multidimensional or multi-aspect approach.

Centrifugal and hydraulic pump manufacturers will benefit from American Smelting and Refining's successful achievement of large-sized castings of its continuous-cast bearing bronze. The bronze is now available in 44 sizes up to 9" in diameter. Casting in such



sizes posed severe engineering problems, and was achieved only after years of research, with many design modifications required. □

CORRECTION

Omitted from the list of industrial firms which have given financial aid to the work of the Research Committee, A.I.Ch.E., (*CEP* September 1955), was the name of Badger Manufacturing Co., fabricator of the distillation unit at the University of Delaware, which generously donated part of the cost of the unit to the Research Committee. □

people

DINSMORE HONORED

Ray P. Dinsmore, director of the Institute and chairman of the special A.I.Ch.E. Council committee which developed an accepted policy on professional standards for the Institute, has been awarded the 1955 Goodyear Medal.

The Goodyear Medal, named in honor of Charles Goodyear and sponsored and presented by the Rubber Division of ACS to a man who has performed outstanding service to rubber science, was given to Dinsmore for his long years of work in the research and development side of Goodyear Tire and Rubber Co., of which he is now vice president for Research and Development. A few of the projects which have moved forward under his guidance are: rayon tire cord, Pliofilm, and the recent Chemigum SL, a special synthetic rubber.

An expert on many phases of rubber chemistry, Dinsmore has added greatly to the literature on physical testing of rubber, compounding, vulcanization, aging and the specific problems of processing and producing synthetic rubber.

Dinsmore graduated from MIT with a degree in chemical engineering in 1914 and has been with Goodyear ever since, with a tour as Assistant Deputy Rubber Director during World War II. Earlier honors ihclude an honorary Doctor of Engineering degree from Case School of Applied Science (1940), and the Colwyn Gold Medal of the Institution of the Rubber Industry (Great Britain, 1948).

Married and the father of two children, Dinsmore has always found time from his duties at Goodyear and his family life to be highly active in many organizations, including now holding the presidency of the American Institute of Chemists, and being a director of A.I.Ch.E.

Perhaps his most important work within A.I.Ch.E. has been, and still is, his chairmanship of the Council committee on professionalism and professional attitudes called the "Dinsmore Committee." Professional responsibility has long been a favorite interest of Dinsmore's, and he is always striving to foster professional attitudes among the younger men in the chemical engineering field. The most recent result of his work with the special Council committee, and his long years of interest in professionalism, appeared recently in the form of the Council statement on Professional Standards (*CEP*, November, 1955, pp. 50-52).

Now that the standards have been written and published, Dinsmore will undoubtedly devote much of his great stock of energy and interest to helping younger men see how they can help themselves and the profession through adopting and living a life of high professional standards, having, in short, a professional attitude as high as Dinsmore's own.

Carbide and Carbon Chemicals Co. names **D. B. Benedict,** pictured left, a vice president of the company, division of Union Carbide and Carbon Corp. Benedict will take over responsibility for long range planning in certain research and development activities and in all programs on synthetic fibers. In addition, Carbide appoints **T. R. Miller,** pictured below, director of development. He joined the company in 1940 and worked in positions including director of plant laboratories in S. Charleston. Miller will headquarter in New York.

Also recently appointed is **K. H. Rowland,** who will take over as works manager located in the New York offices of the company.

The Instrument Society of America elects **Richard N. Pond** vice-president of the organization. He will be responsible for the Society's Technical Div.

Emil Ott appointed director of central chemical research and a vice-president of Food Machinery and Chemical Corporation's Chemical Div. To locate in New York, Ott will head the research center's concentration on long-range research projects in such materials as organics and plastics. He joins Food Machinery after 16 years as director of research with Hercules Powder Co.

William K. Luby joins Sil Flo Corp., Tex., as vice-president and general manager. His 18 years of experience cover engineering, production and chemical, technical and administrative training. Among his duties, Luby will direct manufacturing operations, the technical service dept., and quality control and research.

D. E. Lintala to organic research department of Goodyear Tire & Rubber Co.

PERKIN MEDALIST

Edgar C. Britton, director of the Edgar C. Britton Research Laboratory of the Dow Chemical Co., Midland, Mich., has been chosen to receive one of the American chemical industry's highest awards, the Perkin Medal.

Britton is being honored for his overall contributions to industrial organic chemical development, including his work on synthetic phenol production, silicone resins, and the synthesis of eight of the essential amino acids, the latter a vital development in agricultural chemistry.

Presentation will be made September 1956 this year, as part of the special observance of the centenary of Perkin's synthesis.

CORRECTION

Our apologies for an erroneous statement in the October issue of C.E.P. describing Barnett Dodge as having been elected to honorary membership in the A.I.Ch.E. Dodge, instead, had been given honorary membership in the Chemical Metallurgical and Mining Society of South Africa.

unit to the Research Committee. □

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the chemical engineer in MARKETING

Robert F. Lay elected vice-president and general sales manager by Cooper-Bessemer Corp. board of directors.

Lay joined the company in 1941 and after spending several intermittent years with other organizations in various sales positions, he returned to Cooper-Bessemer in 1946 as head of the stationary applications engineering section. He had been sales manager since the first of this year.

Russell W. Sloan advanced to fill newly-created position of manager of commercial development, Pennsylvania Salt Manufacturing Co. Sloan will direct market analysis, research and development on new and established products new to Pennsalt.

Phillips Chemical Co. names several to staff of new Plastics Sales Div.: **W. C. Douce, J. T. Roach, R. G. Askew** and **C. R. Scott** to district managers. **M. W. Davidson** to supervisor of sales service and development branch. **L. B. Croley, J. V. Smith** and **A. L. Walters** take over as sales service engineers.

Emmett E. Hixon to manager of plastics sales in Cellulose Products Dept. of Hercules Powder Co.

Dorr-Oliver, Inc., transfers sales engineers: **T. C. Reeves** to Dallas, Tex.; **G. H. Koenitzer** to Cleveland; **T. V. Barton** to Stamford, Conn.; and **W. M. Smith** to Cleveland.

Houdry Process Corp. names **Philip A. Burghart** head of market development section, Chemical Div. He headquarters in the Philadelphia offices.

Burghart will oversee development in the marketing of catalysts and chemicals used in the petroleum and chemical industries. The Houdry division was established earlier this year.

Albert L. Shutts is manager of the New York territory, Becco Chemicals Div. of Food Machinery and Chemical Corp. Shutts, with Becco since 1946, will cover part of New England, New Jersey and New York State.

Robert J. Minbiole appointed manager of New Orleans office, Dow Chemical Co. Recently elevated to full sales office rank, New Orleans becomes part of the company's program to broaden sales activities.

Among recent new assignments by Hercules Powder Co., **Roland S. Sawdey** becomes manager of Detroit sales district, Cellulose Products Dept.

In the Synthetics Dept. sales div. the following have been assigned: **J. F. Copeland,** field sales mgr.; **G. E. Osburn,** sales mgr., Wil. dist.; **J. S. Autenrieth, J. G. Little,** industry sales mgrs.; **H. D. Heiser,** sales mgr., Houston dist.; **B. J. Dougherty,** sales manager, St. Louis dist., and **C. S. Skow,** resident technical representative, L. A. dist.

John D. Purdy to specialize in sale of Dravo fabricated piping, grating and stair treads as Chicago district sales engineer, Dravo Corp. Working from headquarters in Chicago, Purdy will serve Chicago-Cook County, Ind., northern Ill. and adjacent areas.

John C. McCauley to sales engineering staff, Hammond Iron Works. His services will extend to the petrochemical and processing industries.

Monsanto Chemical Co. appoints **Herbert S. Parham** to newly-created position of asst. director of sales for planning with the company's Organic Chemicals Div. **J. P. Ekberg, Jr.,** succeeds Parham as sales manager for intermediate chemicals. Monsanto announces also **F. N. Cartan,** sales representative for the Overseas Div. He will locate in the New York office.

Shawinigan Resins Corp. names several to Marketing Dept. staff: **J. W. Criss,** mgr., special projects in N. Y. office . . . **C. A. Godsell,** headquartered in Springfield as New England representative . . . **F. H. Hoyt** and **E. H. Finsilver,** New York office . . . **W. M. Young,** Chicago, and **Leonard Roland,** Los Angeles. **D. H. Fraser** named manager of market research on Springfield, Mass., staff.

Allis-Chalmers Industries Group assigns **Henry M. French** processing machinery sales representative in Tampa district.

John P. Manley named sales manager for General Ceramics Corp. to be responsible for sales and advertising program.

H. M. Harper Co., Ill., names **R. N. Hillner** manager of standard product sales. **J. A. Stevenson** appointed manager of technical sales responsible for all specially engineered products including fastening of titanium and high temperature metals by Aero Div. of the company.

Foxboro Co., Mass., names **Vincent V. Tivy** chief application engineer to coordinate sales engineering, products development and production engineering.

Rockwell Manufacturing Co.'s Meter and Valve Div. opens new branch in Denver with **Orville Cochran** as branch manager. Cochran takes over his position after 25 years' experience with the company.

Necrology

Max Neuhaus, 48, vice-president, Jefferson Chemical Company, in Houston, Texas.

Neuhaus, a member of the Institute since 1948, had served with Jefferson since 1944 when he joined the organization as manager of technical and research dept. He received degrees from Rice Institute, studied in Berlin and earned his doctorate at M.I.T.

Robert Gill, 24, chemical engineer in research and development, Olin-Mathieson Chemical Corp., Malta Test Station, Ballston Spa, N. Y.

Egbert B. Freyer, 53, head of the central control dept. of Spencer Kellogg and Sons, Inc., Buffalo, N. Y.

Richard A. Chaille, 32, rating engineer, Southwestern Engineering Co., California.

William L. Yaroch, 34, vice-president and technical director of Klem Chemicals, Inc., Dearborn, Michigan.

Morris Newman, 28, asst. professor of chemical engineering, New York University.

Glen Walker Cole, vice-chairman of the board of directors and former president of Corning Glass Works in Corning, N. Y.

Cole joined Corning Glass in 1919 and worked in successive positions until he assumed the presidency in 1941. He also served as a director of Dow-Corning Corp. and Corhart Refractories Co.

Peter P. Pap, 36, shift leader, Reichhold Chemical Co., N. J.

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A.I.Ch.E.

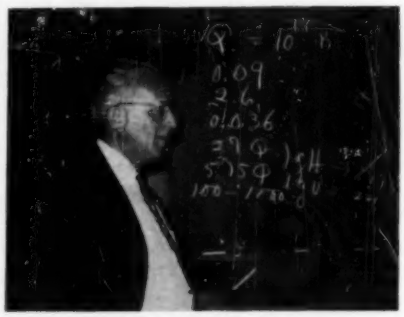
News of the Field

FROM LOCAL SECTIONS

PRESIDENT DODGE TOURS SECTIONS

"Energy Resources" subject of President Barnett F. Dodge's talk to local sections.

Touring the country speaking to local sections, President Barnett F. Dodge was on the West Coast in September to address the **El Dorado, Southern California, Northern California,** and **Washington-Oregon Sections.** The visits of our highly-active President were enthusiastically received on the West Coast as they have been everywhere.



Dodge at El Dorado

In October Dodge turned East and visited the Sections in **Cleveland, Toledo, Twin Cities,** and **East Tennessee,** speaking in the latter case on Teaching Chemical Engineering Abroad. In all but the last section, Dodge delved deeply into the entire problem of industrial energy for the future.

The U. S. uses 40% of all energy consumed in the world, and the problems of energy resources are of special importance to the American chemical engineer. Energy is important to all engineers, but particularly so to chemical engineers.

The petroleum industry alone continues to play a major role in providing energy for industry, especially as natural gas tends to replace other fuels. The fuel and chemical potential of coal is the province of the chemical engineer. Now, with the advent of atomic energy, a drastic impact is being felt on the whole picture of energy resources, changes are growing that challenge the chemical engineer.

Dallas, Tex. Details of the process design performed by Purvin and Gertz for the new Texas Butadiene Company plant at Houston, were discussed by Ed Schutze of Purvin and Gertz at the Oct. 25 meeting of the Dallas Section.

—E. D. Soltes

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Northeastern New York. New idea for starting off the season has just been used by the Northeastern New York Section. Patterned on National A.I.Ch.E.'s pamphlet, "Know Your Institute," a pamphlet "Meet Your Local Section," was mailed to the Section's paid-up membership, plus any other interested persons.

The pamphlet consisted of a statement on why an engineer should join a local section, who is eligible, the history of the section, the officers and committees, a list of members, a report on last year's meetings including the National meeting at Lake Placid, and, particularly, the program of coming events.

Response has been good, the Section feels the project achieved an excellent public relations goal, brought in new members, made old members anxious to sign up again.

—K. S. Watson

Denver, Colo. Are all estimates of future energy consumption by the U. S., and the world, gross underestimates? Russell Cameron, Cameron & Jones, Consulting Engineers, thinks so, and told why to the Oct. 13 meeting of the Rocky Mountain Section.

Rapid population increases and rising standards of living are the basic causes for the rising energy consumption rates, according to Cameron. What this will mean is a widespread use of "low-grade power sources," including oil from shale, deeper mining of coal fields, and lignites. Solar energy will certainly find a place in future energy requirements, and for large installations nuclear energy is certain to be used.

Cameron feels that a major role in future energy problems and developments must be played by the chemical engineer.

—R. M. Berry

Albuquerque, N. M. The annual award of the A.I.Ch.E. at the Univ. of New Mexico for the student maintaining the highest av e of his class during freshman d sophomore years has gone to J. Lott. Prize is a Certificate of Merit, a two-year subscription to *CEP*, a year's membership in A.I.Ch.E., and the official A.I.Ch.E. key.

—R. R. Barrett

New Jersey. The pros and cons of patent versus trade secret was the subject of the Oct. 11 meeting of the New Jersey Section. Speaker K. LeFever, senior patent attorney of Esso Research and Engineering, traced the history of patents and posed the question of patent vs. trade secret. The discussion that followed found good arguments on both sides.

—D. S. Wilt

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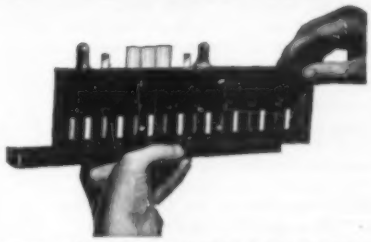

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The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before January 15, 1955, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Adelman, B. R., *Waco, Tex.*
Alcock, John P., *Landenberg, Pa.*
Andrews, Robert V., *College Station, Tex.*
Bachelor, James B., *San Gabriel, Calif.*
Carnell, David W., *Wilmington, Del.*
Carpenter, C. Leroy, *Searsport, Me.*
Cheney, Leroy K., *Los Angeles, Calif.*
Childress, Herman L., *Perth Amboy, N. J.*
Connelly, Frank J., Jr., *South Amboy, N. J.*
Foust, Harold C., *Indian Head, Md.*
Garrett, Donald E., *Trona, Calif.*
Gary, James H., *Charlottesville, Va.*
Gaylord, John W., *San Anselmo, Calif.*
Hatch, Robert L., *Pittsfield, Mass.*
Hope, R. E., *Baltimore, Md.*
Howerton, Murlin T., *Denver, Colo.*
Isbin, Herbert S., *Minneapolis, Minn.*
Keith, Frederick W., Jr., *Gladwyne, Pa.*
Kienker, Ralph W., *Texas City, Tex.*
Loar, J. E., *Port Arthur, Tex.*
Miller, Jack Marion, *Wilmington, Calif.*
Nicolaisen, B. H., *Niagara Falls, N. Y.*
Peterson, Robert J., *Frederick, Md.*
Raymond, Paul L., *Natick, Mass.*
Rose, George M., *Drexel Hill, Pa.*
Selke, W. A., *Cresskill, N. J.*
Silling, C. E., Jr., *Holmes, Pa.*
Stage, Hermann, *Koln-Niehl, Germany*
Sutherland, Sam, Jr., *Freeport, Tex.*
Tate, Roger W., *Pewaukee, Wis.*
Tooke, Raymond, Jr., *Fredericksburg, Va.*

Associate

Ade, C. William, *St. Louis, Mo.*
Ahrens, Herbert W., Jr., *Glen Rock, N. J.*
Ark, W. Fong, *Norfolk, Va.*
Austin, Richard C., *Orange, Tex.*
Barbaz, Charles G., *Bloomfield, N. J.*
Barnett, James V., *Corpus Christi, Tex.*
Bave, William H., *Wilmington, Del.*
Beasley, Orville T., *Texas City, Tex.*
Bernhardt, Howard J., *Port Arthur, Tex.*
Brock, Carl M., *New Castle, Del.*
Cender, Rudolph, *Staten Island, N. Y.*
Chazen, Melvin L., *St. Louis, Mo.*
Christensen, Craig M., *Ithaca, N. Y.*
Christiansen, Robert M., *Worthington, Ohio*
Clarke, Robert G., *Oceanside, N. Y.*
Cleland, Edward L., *Nanuet, N. Y.*
Coffin, John P., *Huntsville, Ala.*
Coons, William R., Jr., *Port Arthur, Tex.*
Cox, Hiram, *Wilmington, Del.*
Crosby, Edwin J., *Wilmington, Del.*
Davis, Robert Stephen, *New Rochelle, N. Y.*
Davis, Ronald L., *St. Louis, Mo.*
De Broux, Pierre, *Shawinigan Falls, Que., Can.*
De Puy, James R., *Midland, Mich.*
Detweiler, Roy R., *Wilmington, Del.*
Devys, Jacques G., *White Plains, N. Y.*
Evans, Daniel G., *Wilmington, Del.*
Ferm, Robert James, *Albuquerque, N. M.*
Ferrari, Lawrence J., *Elizabeth, N. J.*
Fournet, P. H., Jr., *Baton Rouge, La.*
French, Richard M., *Oak Ridge, Tenn.*
Furey, James G., *Whittier, Calif.*
Glass, Robert M., *Danville, Va.*
Goetz, Donald C., *Iowa City, Iowa*
Gossman, James L., *Rochester, N. Y.*
Greene, Robert E., *Midland, Mich.*
Hack, Charles W., *San Antonio, Tex.*
Harding, J. Hilary, Jr., *Henderson, Ky.*
Hering, Carl, *Monterey, Calif.*
Holiday, Allan D., *Carthage, Mo.*
Hunton, John H., Jr., *New Orleans, La.*
Hyland, James W., Jr., *Maumee, Ohio*
Iscol, Lewis, *Madison, Wis.*
Jones, Randall E., *Texas City, Tex.*
Karawan, Henry J., *So. Charleston, W. Va.*
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Pawlikowski, Joseph F., *Keystone Heights, Fla.*
Peterson, Everett L., *La Marque, Tex.*
Pike, Charles W., *Houston, Tex.*
Ply, Eugene N., *Park Forest, Ill.*
Pratt, William H., *Stamford, Conn.*
Reduto, Eugene P., *So. Ozone Park, N. Y.*
Richards, Jack M., *Whiting, Ind.*
Schwartz, Jane P., *New York, N. Y.*
Shoemaker, David R., *Kingsport, Tenn.*
Somers, Ralph W., *Houston, Tex.*
Spann, Delroy O., *Baton Rouge, La.*
Sundjaswadi, Sugeng, *Djocjakarta, Indonesia*
Sung, William N. L., *Los Angeles, Calif.*
Symoniak, Martin F., Jr., *Bartlesville, Okla.*
Szymanski, Dick R., *Ponca City, Okla.*
Tanner, Alvin L., *Manhattan Beach, Calif.*
Tate, G. E., *Waverly, Tenn.*
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Thomas, Burton L., *Houston, Tex.*
Toyoda, K. George, *Richland, Wash.*
Turpin, John N., *Oak Ridge, Tenn.*
Van Buskirk, Oral R., *Wilmington, Del.*
Vandergriff, Jimmy Dean, *Chattanooga, Tenn.*
Waller, Frank W., Jr., *Richmond, Va.*
Walz, Richard, *Aiken, S. C.*
Warner, David B., *Newark, Ohio*
Warren, Robert C., *Detroit, Mich.*
Weaver, T. Bruce, Jr., *Nashville, Tenn.*
Whitaker, Gordon W., *Jeffersontown, Ky.*
Zecco, John J., *Newark, N. J.*
Zeller, Andrew F., *Cheshire, Conn.*

Affiliate

Beutel, A. P., *Freeport, Tex.*
Grimm, Richard C., *So. Charleston, W. Va.*
Holz, Charles, *Charleston, W. Va.*
McGill, Jerome F., *Elgin, Ill.*
Shepard, Harry L., *Houston, Tex.*

News of the Field
FROM LOCAL SECTIONS

Detroit, Mich. The limiting factor to the successful industrialization of radiation power will not be a matter of supply, and probably not of cost either. It will always be a by-product of atomic power, and as such its cost will be adjusted to meet market demands.

This was the consensus of a panel discussion of Radiation Chemistry by panelists B. L. Manowitz, Brookhaven, L. C. Anderson, Univ. of Mich., and J. J. Martin, Univ. of Mich., before the Detroit Section.

No large-scale commercial processes currently employ radiation sources. Nevertheless, several development projects are underway for such applications as sterilizing meats and drugs, treating potatoes to prevent sprouting, etc. Possible new applications are: Production of graft copolymers to give plastics special properties, i.e. Teflon grafted with acrylonitrile to give a product with desirable adhesive qualities; preparation of ethylene glycol from methanol; production of benzene hexachloride; preparation of special polymers of ethylene.

—L. R. Chrzan

Baltimore, Md. Because of the relatively high quantities of heat required for certain chemical processes, the cost of fossil fuels becomes high in the effort to get fair utilization. This was the basic reason advanced by R. H. Graham, Division of Reactor Development, AEC, for possible utilization of nuclear energy in the chemical process industries at the Oct. 11 meeting of the Maryland Section.

While fossil fuels are high cost for these applications, the costs of U-235 may be expected to decrease, because of better techniques, etc., and the use of atomic energy as a heat source becomes more attractive to the process industries. Its importance to such processes as coal gasification and direct nitrogen fixation, where large heat requirements exist, is clear, but these are only two applications where use of nuclear energy in the near future seems likely.

—C. G. Schmitz

Charleston, W. Va. Investment requirements vary according to the individual, making it a truism that each individual, in the long run, must work out his own investment program. This was the main point of J. E. Nida, Merrill, Lynch, Pierce, Fenner and Beane, speaking to the Oct. 18 meeting of the Charleston (W. Va.) Section.

—A. W. Byer

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News of the Field

FROM LOCAL SECTIONS

Springfield, Mass. New officers for 1955-56 are: R. G. Carter, chmn.; A. G. Erdman, chmn.-elect; W. M. Underwood, secretary; Marvin Kopp, treas.; R. L. Hatch, director.

—W. M. UNDERWOOD

New Haven, Conn. While the equipment necessary for low-temperature purification is complicated, small packaged units can be supplied to consumers. The October meeting of the New Haven Section heard this from D. Baker, Air Products, Inc.

Low-temperature purification is a major process today, used to produce high purity oxygen, nitrogen, argon, methane, carbon monoxide and ethylene.

—R. W. MICKELSON

Southern California. They're still trying to pin-down "Operations Research." Latest attempt is a characterization rather than a definition. F. Hulswit, Arthur D. Little, speaking before the Oct. 18 meeting of the Southern California Section, says that operations research is characterized by the use of a team of researchers who apply the scientific approach, especially the use of mathematical models, to the problems of business administration. Operations researchers study a problem in management the way other engineers study a problem in design, from the standpoint of causes, while the executive is more concerned with dollars.

—F. G. SAWYER

Boston, Mass. In spite of its large expanse of desert, Egypt must import the sand for its glass factory from Belgium. With this as a prime example of the engineering problems facing anyone in the Middle East, L. Bass, vice president of Arthur D. Little, dug into the whole problem of developing the Middle East at the October 21 meeting of the Boston Section.

The problem, in essence, boils down to one of outside help and "bootstrap-raising." While the Middle East is dotted here and there with modern industrial installations, such as refineries, textile mills, and hydroelectric projects, the area as a whole is badly in need of transportation, mechanization, and all the other physical improvements. Islands of industry will remain islands until the general level is raised everywhere, and that means better education and modern management and engineering methods as well as improved technology.

—A. S. COLLINS

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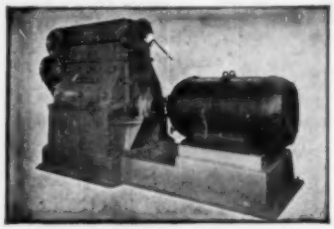

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CHEMICAL ENGINEER—B.Sc., age 26, 6½ years' industrial experience, mostly production, responsible positions. Desires work in sales or technical representation. Prefer company doing business with Europe. Box 25-12.

News of the Field

FROM LOCAL SECTIONS

Northern California. 1955-56 officers are: T. E. Drisko, Jr., Dow, chmn.; N. K. Hiester, Stanford Research Inst., vice-chmn.; J. E. Walkey, Jr., California Research Corp., secretary; and D. N. Hanson, Univ. of California, treas.

—A. W. FAIRBAIRN

Kansas City, Mo. The jet engine automobile is still a long way off, according to J. H. Forrester, Standard Oil (Indiana), speaking before the Oct. 26 meeting of the Kansas City Section.

The meeting, a plant trip through Standard's Sugar Creek refinery, was climaxed by Forrester's talk on catalytic reforming. Emphasizing the tremendous percentage increase in gasoline produced from crudes, Forrester also stressed the many by-products of reforming operations.

On the way the problem of "smog" came up, and it was admitted that automobile exhausts must certainly share the blame.

—L. S. DEATLEY

El Dorado, Ark. American Cyanamid's Fortier plant, New Orleans, La., is a completely integrated operation producing ammonia, sulfuric acid, ammonium sulfate, acetylene, hydrogen cyanide, and acrylonitrile. And in this very integration lies its main problem. Describing this highly interesting plant to the Oct. 21 meeting of the El Dorado Section, T. W. Baker, Cyanamid, went to considerable detail.

The problem caused by integration arises when the plant goes on stream. It is a difficult plant to get on stream, and difficult to keep there. A major cause of this is corrosion failure. With corrosion affecting one section, that section must be shut down, and, because of the complete integration, this means curtailment or even complete shutdown of the rest of the plant.

The raw materials alone indicate the integration. Natural gas, sulfur, and air are the raw materials for all products. Air is separated into oxygen and nitrogen. Nitrogen and natural gas (via hydrogen from natural gas reforming) are used to make ammonia. Oxygen and natural gas produce acetylene. Ammonia and air make hydrogen cyanide. Ammonia and hydrogen cyanide produce acrylonitrile. Ammonium sulfate is a by-product sold for fertilizer. Truly an integrated plant.

And Cyanamid is not standing still, new facilities at Fortier will produce monomethyl styrene, acrylamides, and polyacrylamides.

—W. L. BREAK

Inside—Outside Topside!

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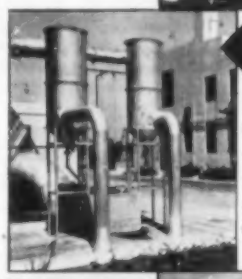

Outside

Installation of collectors outside the plant, conserving floor space for productive work.

Topside

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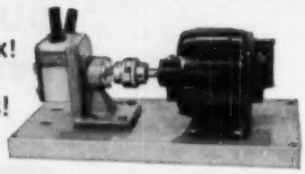

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news and notes

AN ACCOUNTING OF STEWARDSHIP . . . I should like to make the final column of each year a personal column to you, the members -- one that will evaluate the accomplishments, assets, deficits, and ambitions of the A.I.Ch.E.

This has been a year of accomplishment, and if I were to name one undertaking which stands out more than any other, I should select the launching of the A.I.Ch.E. Journal. This magazine, which will report the basic chemical engineering science behind our profession, began as a quarterly and we intend to continue it as such in 1956.

Another important development involves the Nuclear Engineering Division and the interest of chemical engineers in the nuclear field. The Nuclear Division and the A.I.Ch.E. were part of the Nuclear Congress. Concurrent with the Congress, the A.I.Ch.E. also sponsored an atomic energy exposition. It is our intention to hold a meeting of the Nuclear Engineering Division in 1956 from September 29 through October 5 in Philadelphia, along with another atomic exposition. This activity could have a far-reaching effect on the future of the Institute if the nuclear field fulfills its expectations and especially if chemical engineers continue to play a prominent part.

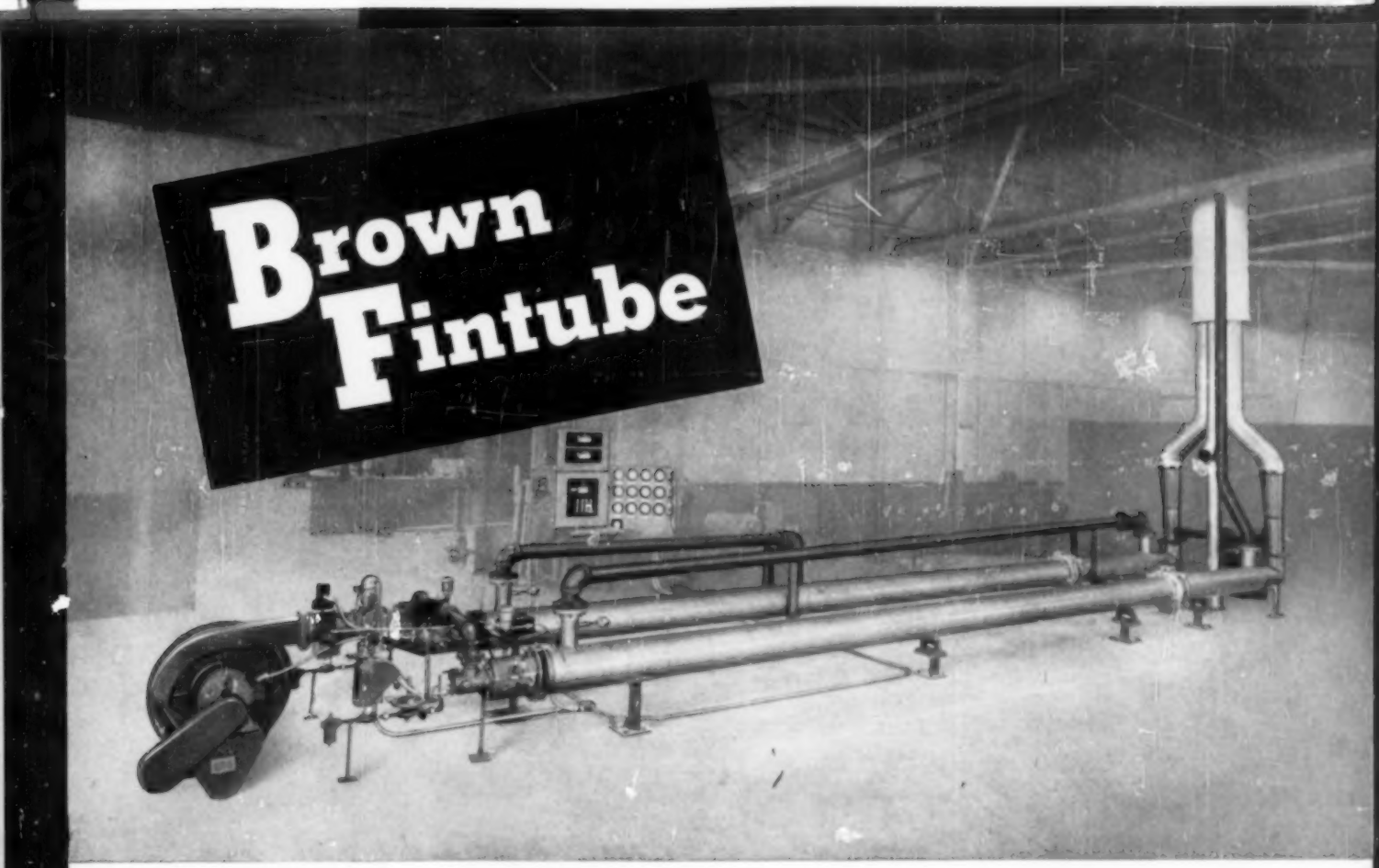
The dues increase is of great membership interest. Council became concerned with our decreasing reserves early in 1955 and, faced with a budgeted loss of $25,000, which would have placed the reserves in a dangerously low position, it felt that the membership would be willing to support a dues increase of one sixth. The increase was not lightly voted; it followed a long debate. But inflation and more services had increased our expenses, and Council felt that a society of professional men supporting professional ventures would suffer no membership loss if the members were asked to pay $2 or $3 more a year. Incidentally, the $25,000 budget loss did not occur, and the question in my mind as I write this column is whether or not there will be any deficit in 1955 at all. The operating economies that we practiced in 1955 made it difficult to put into effect desired objectives. In the main, however, much was accomplished. Our publication activities, aside from the magazines, have continued with gratifying results: The Nuclear Division through Charles Dryden has surveyed college programs in nuclear engineering and collected its findings in a pamphlet of that title. The Student Chapters Committee, under Dysart Holcomb, has rewritten the "Student Chapter Guidebook." The Chemical Engineering Education Projects Committee, through Robert Kintner and Frank Anderson, has reissued the Institute publication on chemical engineering problems; a new section on nuclear engineering has been added. The "Chemical Engineering Faculties" list has been issued for the 1955-1956 period and is chiefly the work of Kenneth A. Kobe.

Communications to members is and probably will always be a major problem. This column is suppose to help, but another move has been made. During the year we created a "V.I.P." list, composed of Council members, committee personnel, local section officers, student chapter counselors, and representatives to other groups, and to this list we send various news items, all the new pamphlets, and letters designed to tell them something about the operation of the Institute. We hope thereby to create a feeling of camaraderie and to transmit to them the conviction that the A.I.Ch.E. has achieved a remarkable speed toward the right goals.

As Secretary, may I add this personal note that this has been a year of pride and satisfaction for me and that I am convinced that all the problems which now seem so difficult of solution will shortly be behind us and that the profession of chemical engineering will continue to go forward. As I said at the annual Business Meeting, in Detroit, the careful decisions of Council in weighing the many possibilities and in solving the problems which arose during the year are splendid examples of the sincerity and unselfishness and ability of professional men when faced with conditions that require clear thinking and financial courage.

My final wish for 1955 is a Merry Christmas and a happy and professionally progressive New Year for all.

F.J.V.A.



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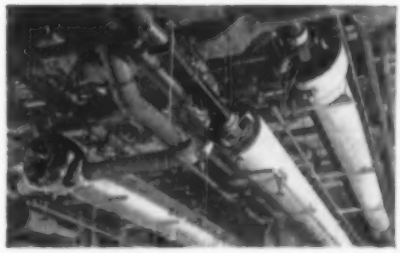
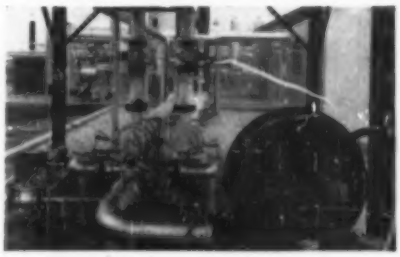


Above: Three Brown Fintube Air Heaters Mounted from Ceiling to Save Floor Space.

Below: Outdoor Installation of Two Gas Fired Heaters.



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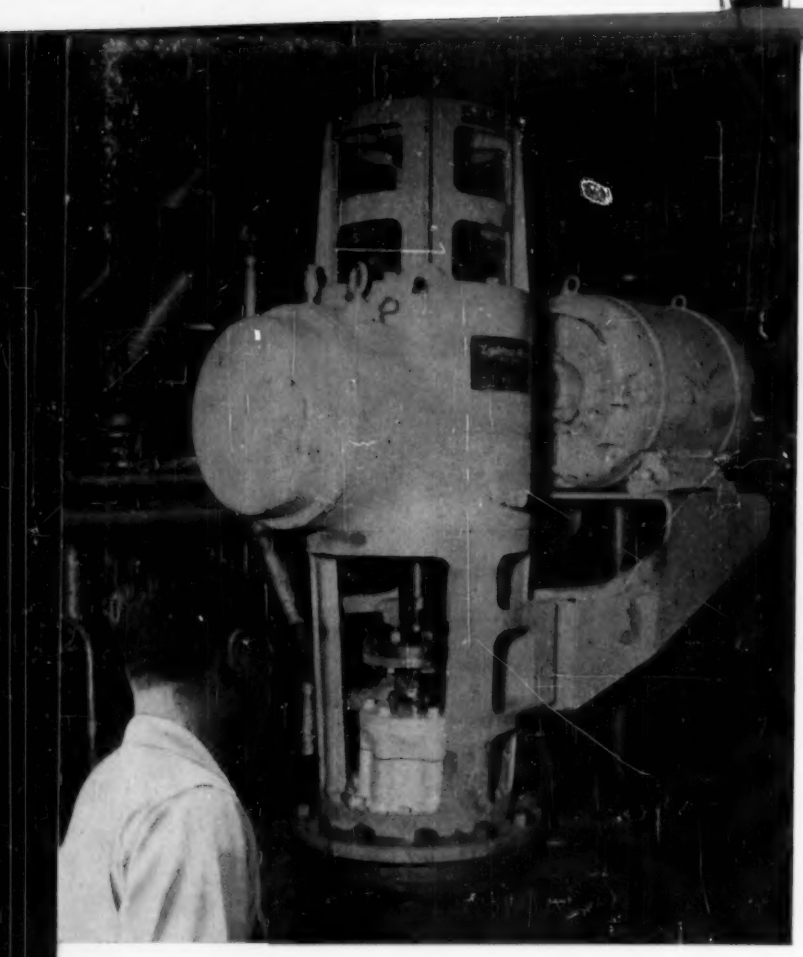

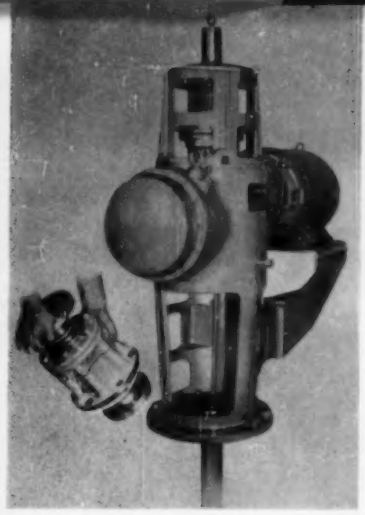

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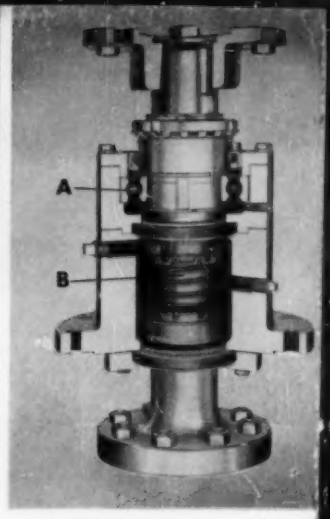

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